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# ENDEAVOUR

A quarterly review designed to record the progress of the sciences in the service of mankind

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UNIVERSITY OF PENNSYLVANIA

# Endeavour

VOLUME III 1944

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# ENDEAVOUR

A quarterly review designed to record the progress of the sciences in the service of mankind

VOLUME III JANUARY 1944 NUMBER 9


# Two chemical anniversaries

There were two fundamental factors in the unparalleled scientific progress of the nineteenth century. One was the formulation of the chemical atomic theory. The other was the establishment of the principle of the conservation of energy. Both were the work of British scientists. The indestructibility of energy was demonstrated by James Prescott Joule. The chemical atomic theory sprang from the genius of John Dalton, the centenary of whose death falls in this present year 1944. From the time of Boyle (1627–91), Britain has produced a succession of great scientists—astronomers, physicists, chemists, biologists, geologists—hardly equalled, and certainly not surpassed, by those of any other country. In this succession were some whose work was not merely great, but epoch-making in the literal sense of the term. Newton, for example, marks the starting-point of modern physics; Darwin's *Origin of Species* was a definite milestone in biology; and J. J. Thomson erected an equally unmistakable frontier sign by his work on the conduction of electricity through gases. It is in such company that Dalton finds his proper setting.

Seldom has the hour more appropriately produced the man. Ten years before Dalton's birth in 1766, Joseph Black had published the first quantitative chemical investigation carried out in accordance with rigid scientific canons. In this work, which dealt with the relationship between the mild and the caustic alkalis, Black had recourse to the balance at every turn, and tacitly assumed both the conservation of matter and the constancy of composition of individual chemical substances. During the succeeding twenty years, the 'age of pneumatic chemistry' was signalled by the discovery of most of the common gases, and by Lavoisier's brilliant elucidation of the composition of the atmosphere. Like Black, Lavoisier appears to have accepted the constant composition of chemical substances as axiomatic, but this view was challenged by his contemporary Berthollet. About 1802, however, Proust settled the question by numerous analyses. Differentiating between a mixture or solution and a chemical compound, he proposed to employ constancy of composition as a touchstone for chemical combination.

Thus new substances, new facts, new methods, and new concepts were to be found in profusion at the opening of the nineteenth century. They called for an informing, integrating generalization: and this was already taking shape in the mind of John Dalton, then an obscure mathematical coach in Manchester.

Born of sturdy yeoman stock, Dalton was characterized even as a schoolboy by his determined reliance upon his own powers. Presented with a difficult problem, he delighted in worrying it out for himself and would decline offers of help from his teacher. 'Yan med deu 't' ('I may do it') was has customary answer, and his confidence was generally well founded. This dogged persistence in mental effort was a happy reinforcement of the profundity of his thought, for he did not think quickly and his contributions to scientific theory were the fruit of prolonged travail. His atomic theory, gradually elaborated during some ten years, was fully published in 1808, in the first part of his *New System of Chemical Philosophy*. Though he was originally led to its formulation by his investigation of the physical properties of gases, he came to perceive that valuable confirmation of its main tenets might be obtained from a study of the relative weights in which elements react together. With the simplest of apparatus, he conducted painstaking experiments on this point, and discovered—as he firmly expected to discover—that each element appeared to consist of particles alike in weight for the same element but varying in weight from element to element.

This was the talisman which very quickly began to knit together the mass of discrete and disconnected chemical data by then accumulated. Chemistry became a unified science, and to a great extent an exact science. The theory in its original form, like all comprehensive theories, required clarification in some respects and modification or extension in others. Dalton himself failed to appreciate the vital distinction between atoms and those aggregates of atoms later called molecules. That was left to the insight of Avogadro and the common sense of Cannizzaro. But, with the general acceptance of Dalton's theory—particularly when its use was simplified by the addition of Berzelius' system of chemical notation—chemistry was well launched on a flowing tide. Today the Daltonian hypotheses have suffered the fate inevitable to all scientific hypotheses: they have been absorbed in, or replaced by, more accurate descriptions of phenomena—but for a hundred years they charted the chemical ocean.

Nor was it only the ocean of academic chemistry, for the atomic theory was in fact the indispensable basis of the development of the chemical industry, and therefore exerted an influence stretching far beyond the confines of the laboratory. It would be a not uninteresting task to try to evaluate its effect upon the history of the world.

Dalton's epoch is now past; but on looking back we can recognize it as one of the most clearly defined epochs in the whole growth of science. With sure prescience he had seen the point 'towards which the rays of scattered experiments were converging,' and slowly, but with equal sureness, he brought them all to a sharp and illuminating focus.

If tradition is to be trusted—and in this case it is not unduly suspect—the year 1944 will witness another notable anniversary. Exactly 800 years ago, on 11th February, 1144, the English scholar Robert of Chester finished his Latin translation of an Arabic work on alchemy. The translation circulated in Western Europe, and there are grounds for believing it to be the first alchemical text to reach Latin civilization. Though (as Professor Tenney L. Davis pointed out in our last issue) alchemy presupposes the existence of a considerable body of chemical knowledge, development in Europe was from alchemy to chemistry. Hence, if any one day more than any other may be honoured as the birthday of chemistry, it is 11th February, 1144. Whatever the facts, Britain can at least claim that, less than a century after the Norman Conquest, her scholars were seeking out new avenues of learning.

Robert was probably a native of Ketton in Rutland, and owed his cognomen to the fact that he was educated at Chester. Following a widespread custom of the period, he made a lengthy sojourn in Spain in order to assimilate Islamic scholarship. A letter written in 1143 by Peter the Venerable to St Bernard relates that in 1141 Peter came upon Robert and his friend Hermann of Dalmatia—two 'acute and well-trained scholars' residing near the Ebro—and persuaded them to leave their astrological studies for a time and to undertake the translation of the Koran into Latin. This task was completed in 1143; and Robert appears to have returned at once from doctrinal to secular subjects, for the translation of the alchemical text in 1144 was followed in the succeeding year by the first translation of the Algebra of Al-Khwārizmī. The importance of this particular translation would be difficult to overestimate, for it marks the beginning of European algebra.

About 1147, Robert (who had held the office of Archdeacon of Pamplona) returned to England, where he wrote or translated a treatise on the astrolabe, compiled astronomical tables for the longitude of London, 1149–50, and revised for the meridian of London the tables of Al-Khwārizmī previously translated by Adelard of Bath. A minor contribution to mathematics was his use of the word *sinus*, sine, in its trigonometrical sense, as a translation of the Arabic *jaib* (pocket) with the same trigonometrical meaning.

The reign of King Stephen is now so remote as to border on the legendary. It is a pleasant reflection that even in those 'times long gone before' Englishmen were not only advancing the bounds of knowledge but were working in harmony with scholars of a different race and a different creed.

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Contributions and correspondence should be sent to the editor: E. J. Holmyard, M.A., M.Sc., D.Litt., F.I.C., Imperial Chemical Industries, Nobel House, Buckingham Gate, London, S.W.1. Scientists engaged in research of an interesting or important character are invited to send short notes on work in progress and results obtained.

# Penicillin

E. CHAIN and H. W. FLOREY

Penicillin, perhaps the most valuable chemotherapeutic agent yet known to science, was a purely British discovery. Yet so prone are British scientists to the national habit of reticence and understatement that in the newspapers credit was not always assigned to the proper quarters. We are happy to be able to publish this authoritative article by Dr Chain and Professor Florey, to whom much of our detailed knowledge of penicillin is due.

The demonstration of the remarkable therapeutic possibilities of the mould product penicillin has led to publicity in the lay press much of which is characterized by a lack of real knowledge of the subject. It may therefore be of interest to trace the development of the use in medicine of this and other substances produced by micro-organisms.

Penicillin is an antibacterial agent produced by a mould. Its formation represents one example of the widespread phenomenon of 'microbial antagonism.' Many species of bacteria and fungi are able, under suitable conditions, to interfere with or prevent the growth of other microbial species. It has now been established that this inhibitory action is in many cases due to the properties of metabolic products formed by the antagonist. The term 'antibiotic' has recently been suggested (Waksman *et al.*, 1942) to designate these substances.

We have to go back more than sixty years for the first suggestion that the phenomenon of microbial antagonism had therapeutic possibilities. Pasteur and Joubert in 1877 described the antagonistic effect of certain contaminating organisms on the growth of the anthrax bacillus. Some of their observations led them to state: 'Tous ces faits autorisent peut-être les plus grandes espérances au point de vue thérapeutique.'

The first serious attempt to employ an antibiotic for curative purposes was that of Emmerich and Loew, who in 1899 utilized the discovery of Bouchard (1889) that *Pseudomonas pyocyanea* was antagonistic to other species of bacteria. They showed that culture medium on which *Ps. pyocyanea* had been growing for a long time had the property of dissolving or killing many pathogenic bacteria. This phenomenon they ascribed to the action of an enzyme 'pyocyanase.' They claimed that experimental anthrax could be cured by pyocyanase and suggested its use for the local treatment of diphtheria and other infections. The clinical efficacy of pyocyanase was questioned by most subsequent observers, but nevertheless it appears to have been on sale in Germany till as late as 1936. Much (1924) suggested the clinical use of antibacterial substances produced by the subtilis-mesentericus group of bacteria.

The production by strains of actinomyces of a substance 'actinomycetin,' capable of dissolving certain pathogenic bacteria, was described by Gratia and Dath (1924). They suggested (1934) that suspensions of bacteria which had been dissolved by actinomycetin could be used for immunizing purposes, and claimed that such 'mycolysates' were more effective than the ordinary vaccines. This technique has not found acceptance in medical practice.

Dubos in 1939 demonstrated the presence of an antibacterial agent in culture filtrates of a soil organism, later recognized as *Bacillus brevis*. This agent was shown to consist of two polypeptides, gramicidin and tyrocidine, which were isolated in the crystalline state. 'Tyrothricin,' the crude mixture of the two polypeptides, has been used locally with some success for the treatment of infected wounds, but it is too toxic for general administration.

### THE DISCOVERY OF PENICILLIN

A particularly striking example of microbial antagonism was discovered in 1929 by Professor A. Fleming. A green mould, an accidental air contaminant, grew on an agar plate which he had used for the cultivation of staphylococci. He noticed that in the neighbourhood of the contaminating mould the colonies of staphylococci were dissolving (figure 1). Subcultures of the mould were made in order to study its antagonistic behaviour towards staphylococci and other organisms in greater detail. Fleming showed that the mould, which was subsequently identified as

*Penicillium notatum* (figure 2), could be grown on a liquid medium (peptone broth), and that it secreted something into the medium which inhibited the growth of many pathogenic bacteria, even when the broth was diluted as much as 800 times. The susceptible bacteria included pathogenic organisms such as staphylococci and streptococci, which produce some of the most destructive infective lesions in man; other bacteria, such as *Bacterium coli* and *Salmonella typhi*, were not affected (figure 3).

Fleming ascribed the power of the medium to inhibit the growth of bacteria to the presence of an antibacterial agent which he named penicillin. He also noted that broth containing penicillin was not more toxic than ordinary broth when injected into rabbits and mice, and that leucocytes were little affected by it.

Fleming appreciated the possibility that penicillin might be a useful substance to apply as an antiseptic locally to infected wounds, and indeed some cases of indolent septic wounds were so treated. Fleming stated that penicillin 'certainly appeared to be superior to dressings containing potent chemicals' (Fleming, 1932).

The really extraordinary good fortune surrounding Fleming's acute observation of the antibacterial action of his mould contaminant is only now becoming apparent. *P. notatum* is not a very common mould—in fact, contamination of a bacterial culture with it is probably infrequent. In addition, as subsequent work has shown (Waksman, 1941; Wilkins and Harris, 1943), there are many moulds which produce antibacterial substances. Figures 4, 5, 6, and 7 show inhibition of the growth of staphylococci produced by *P. notatum*, *Aspergillus giganteus*, *Penicillium cyclopium*, and *Aspergillus terreus* respectively. The substances produced by the first two moulds have been found to be non-toxic, while those from the last two are very toxic. This emphasizes the point that only after extraction of the active substance, and sometimes after considerable purification, can its therapeutic possibilities be ascertained.

Following Fleming's work, Clutterbuck, Lovell, and Raistrick (1932) endeavoured to isolate penicillin. They showed that penicillin was formed when the mould was grown on a synthetic culture medium, and this, they thought, would facilitate its isolation. They concluded that it was a very labile substance, and as the extraordinary properties of penicillin were not realized at the time, the work was not pursued. They found that concentration of the culture medium at 40° C *in vacuo* inactivated penicillin; that it could be extracted from the culture medium with ether after acidification; and that the greater part of its activity was lost on evaporation of the ether solution in a stream of air.

Little further interest seems to have been taken in the isolation of penicillin and its possible application to medicine, though Reid (1935) reported a few experiments which tended to show the labile nature of the active substance.

Though discovery of the chemotherapeutic effects of penicillin has overshadowed its use in bacteriology, Fleming (1932) found that it is a very useful ingredient of culture media, suppressing the growth of sensitive organisms while permitting the growth of insensitive species. In this way it is possible, for example, easily to separate the influenza bacillus of Pfeiffer from accompanying organisms such as the streptococcus. Fleming has used this differential medium for various purposes ever since his original observations, the crude penicillin-containing culture medium being adequate for bacteriological purposes (Fleming, 1929, 1932; Fleming and Maclean, 1930).

### THE DISCOVERY OF THE CHEMOTHERAPEUTIC PROPERTIES OF PENICILLIN

Through an interest in the problem of natural immunity, one of us (Goldsworthy and Florey, 1930) began to study the properties and physiological significance of a powerful natural antibacterial agent, lysozyme. This substance, discovered by Fleming, is widely distributed in nature, occurring in egg-white, bacteria and plants, and many animal tissues. The work on lysozyme was pursued until it was finally purified (Roberts, 1937), and its nature and mode of action as a carbohydrate-splitting enzyme were established (Meyer *et al.*, 1936; Epstein and Chain, 1940). In 1938, during the course of this work, the writers of the present article concluded that it might be profitable to conduct a systematic investigation into the chemical and biological properties of antibacterial substances produced by micro-organisms. Though the existence of such substances had been clearly established in many cases, very little was known at that time about their chemical and biological properties, and it was hoped that a systematic study might lead to the preparation of new compounds of biological interest. By great good fortune one of the first to be investigated was penicillin, which, despite the unfavourable account in the literature

of its chemical properties, showed interesting biochemical and biological characteristics. It seemed important to obtain detailed information about the chemical nature of a substance which inhibited the growth of many pathogenic bacteria, apparently in high dilutions. That this substance prevented the growth of staphylococci appeared particularly important, as no substance was known that effectively controlled staphylococcal infection. In view of the statements of Fleming, and of Clutterbuck, Lovell, and Raistrick, that neutralized sterile culture filtrates containing penicillin might retain their antibacterial activity unchanged for many weeks, it appeared likely that conditions might be found in which the active substance could be isolated and purified.

The first problem presenting itself in the attempt to isolate penicillin was to find a simple and quick quantitative test for the substance. The serial dilution method normally used in bacteriological work was considered too complicated for frequent assays, as it required the absolute sterility of each sample to be tested. A suitable assay method was devised by Dr N. G. Heatley. It may be of interest to describe his method, as it has proved invaluable not only for the work on penicillin but also for similar investigations on other antibacterial products (figure 9).

An agar plate is seeded with the test organism—*Staphylococcus aureus* has been used as a routine—by pouring on a broth culture of the organism, draining off the excess, and drying the plate for 1–2 hours in the 37° C incubator with the lid raised. Short open-ended cylinders of glass or vitreous porcelain are then placed on the surface of the agar, and the solutions to be assayed are placed in the cylinders. After incubation, the surface of the agar becomes covered with a continuous film of bacterial growth except for a circular zone around each cylinder where the penicillin has diffused out and inhibited growth. The diameter of this zone is related to the concentration of penicillin in the solution in the cylinder, and by setting up solutions containing known amounts of penicillin a curve relating the two can be drawn. The actual diameter of the zone produced by any given solution varies slightly from day to day, since it depends on a number of factors, some of which are difficult to control in practice; but the variation can be countered by including one or more solutions of known strength in each assay.

For the same reasons which apply in the case of other biologically active agents of unknown purity, it was found convenient to express the antibacterial activity of penicillin in terms of some standard preparation of penicillin. The 'unit' originally taken for convenience in this laboratory only has since been adopted as the 'Oxford unit' by some other workers. It was defined originally as that amount of penicillin contained in 1 ml. of a certain purely arbitrary stock solution. The latter was exhausted long ago, but other primary standards, in the form of dry preparations, were standardized against it. Until penicillin is obtained in a clearly characterizable form the only way in which the potency of a given solid or liquid preparation can be measured in terms of Oxford units is by a direct comparative assay against a preparation containing a known number of these units. A rough indication of the size of the unit may be gathered from the following facts:

(1) Pure penicillin contains about 1,000 units per milligram.
(2) Most strains of staphylococci are usually inhibited by a concentration of 0·01 to 0·05 units per millilitre.

Using Heatley's test method, it was quickly established that penicillin was an acid of low molecular weight, soluble and stable in various organic solvents, but stable in water only between *p*H 5 and 7. It was found possible—in confirmation of the results of Clutterbuck, Lovell, and Raistrick—to extract penicillin into ether at an acid *p*H; from the ether solution penicillin could be re-extracted into water in the form of its salts by adjusting the *p*H to neutrality. During these operations no loss of antibacterial activity occurred as long as the solutions were kept cold. These observations have formed an integral part of every extraction method since used. Chloroform and amyl acetate are used now for the extraction and purification of penicillin on a large scale.

On evaporation of the watery solution *in vacuo* from the frozen state, a dry penicillin salt preparation was obtained which retained its activity for long periods. The first crude preparations made by extracting penicillin from the culture medium into ether and back into water contained, as we now know, only about 1 per cent. of pure penicillin. However, even these very crude preparations inhibited the growth of staphylococci and other bacteria at a dilution of 1 part in 500,000. This antibacterial effect was of the same order of magnitude as that of many powerful antiseptics, e.g. acriflavin. Not realizing what an extraordinarily powerful antibacterial substance penicillin was, we thought it had been obtained

in a relatively highly purified form and went on to test the toxicity of this crude preparation. Intravenous injection into mice showed that it possessed a low toxicity—20 gm. mice survived an injection of 10 mgm. with little or no toxic effect. It was also seen that penicillin appeared very rapidly in the urine of the injected animals. After these encouraging findings it was decided to carry out a small-scale therapeutic experiment on eight mice infected with haemolytic streptococci. Four of these animals were treated with repeated injections of the crude penicillin salt preparation and four served as a control. One of the treated animals survived indefinitely, while the three others died many days later than the untreated ones, which succumbed within 24 hours. This experiment was sufficiently encouraging to make it seem probable that penicillin had chemotherapeutic potentialities, and it became apparent that results would be obtained most quickly by the co-operative effort of a team of workers. The most urgent immediate problems to be tackled were: (1) to produce larger quantities of penicillin, which, it was found, was produced by the mould only in very small amounts; (2) to make a thorough study of the biological properties of penicillin; (3) to purify penicillin as much as possible and to study its chemical nature.

We were particularly fortunate in our collaborators. Dr N. G. Heatley not only devised the rapid and simple assay method described above which made it possible to carry out all subsequent work expeditiously, but designed and constructed the first large-scale laboratory plant for growing the mould and extracting penicillin. Dr A. G. Sanders later devised and built alternative apparatus for the extraction of penicillin on a larger scale. Professor A. D. Gardner collaborated throughout on the bacteriological aspects of the work and Dr M. A. Jennings on the biological investigations. Later Dr E. P. Abraham joined us for the chemical investigations. When the stage of therapeutic trials on man was reached, Dr C. M. Fletcher and, later, Dr M. E. Florey were responsible for the clinical observations, with the help of many physicians and surgeons.

The large-scale preparation of penicillin was carried out in Oxford by Mr G. Glister and his assistants and Mr J. Kent. In the purification of the penicillin the skilful technical assistance of Mr D. Callow has been invaluable. In the later stages of the work Mr Callow has had the help of Mr J. B. Burtt.

For the preparation of larger amounts of penicillin special culture vessels were used, each containing about 1 litre of culture medium. The synthetic medium described by Clutterbuck, Lovell, and Raistrick was employed, with yeast extract added to accelerate the growth of the mould. Considerable difficulties were encountered in the first attempts to grow the mould on a larger scale. The main difficulty was soon traced to the fact that contamination by atmospheric bacteria occurred more frequently when working with large culture vessels. Certain of these air bacteria produced an enzyme destroying penicillin (Abraham and Chain, 1940), so that when they were present as contaminants in the medium any penicillin produced by the mould was promptly destroyed. This observation was of the greatest importance and explains why it has been so difficult to produce penicillin on a large scale. Large-scale aseptic procedures need meticulous care, and much of the development work of commercial firms has been devoted to overcoming contamination by the ubiquitous air organisms.

The crude penicillin preparation proved to be fairly stable. When larger amounts became available, attempts were made to obtain penicillin in the pure state (Abraham and Chain, 1942). As is now known, the crude penicillin salt preparations are mixtures of very many different substances. The isolation of penicillin from this mixture was no easy problem because of its instability towards many chemical reagents and the unfavourable solubilities of the free acid and its salts. It was found not only that penicillin was destroyed by acid and alkali but that it was inactivated by many metal ions, in particular by zinc, cadmium, copper, and mercury. The alkali and alkaline earth salts were stable but extremely soluble in water; no organic cation forming a relatively insoluble salt with penicillin suitable for purification purposes was found. Penicillin was also destroyed by primary alcohols, primary amines, ketonic reagents and oxidizing agents; it was, however, found to be stable towards reduction with various reducing reagents.

The methods which could be used for the purification of penicillin were therefore limited to distribution between different solvents and to adsorption methods. Extensive and successful use has been made of chromatography. By a suitable combination of distribution between solvents, various methods of chromatography, and a reduction process by aluminium amalgam (which does not affect penicillin but changes the solubilities and chromatographic behaviour of impurities) it

has been possible to obtain barium salts possessing an activity of about 1,000 Oxford units per milligram. Recently, crystalline preparations of salts of penicillin have been obtained, so that the limit of purification seems to have been reached.

Work on the constitution of penicillin has been carried out in Oxford in the Sir William Dunn School of Pathology by Dr E. P. Abraham and one of us (E.C.), and since 1942 in collaboration with Dr Wilson Baker and Sir Robert Robinson in the Dyson Perrins Laboratory. Subsequently many other workers both in England and America joined in the attack on various aspects of the problem, and especially in relation to production and purification. We can speak only in general terms of the chemical work in Oxford which has led to the elucidation of the constitution of the breakdown products of penicillin and opened the way to eventual synthesis. Before the publication of technical details was prohibited a few brief progress notes appeared in *Nature*. These were of a preliminary character and retain little more than historical value. A characteristic breakdown product of penicillin, penicillamine, has been described (Abraham, Baker, Chain, and Robinson, 1943). This substance, an amino-acid, is obtained by acid hydrolysis of penicillin. Another breakdown product, penillic acid, has been found by Duffin and Smith (1943). This substance is formed on acid inactivation of penicillin.

The purest preparations of penicillin inhibited the growth of staphylococci at the astonishing dilution of 1 part in 50 millions; a strong partial inhibition was obtained in a dilution of 1 part in 150 millions. Gonococci and meningococci were about twice as sensitive as staphylococci. Table I illustrates the relative activity of penicillin against a wide range of bacteria. The results recorded agreed with those originally found by Fleming on crude penicillin-containing culture medium, with the addition of the important group of gas gangrene organisms among the sensitive and the tubercle bacillus among the insensitive species. It is noteworthy that *Actinomyces bovis* was sensitive. The figures in this table are of comparative value only, as they were derived from experiments with crude penicillin. (A typical 'dilution test' is shown in figure 8.)

The extraordinary potency of the antibacterial action of penicillin would not by itself make this substance unique, for Waksman and Woodruff (1941) have isolated an antibacterial agent, actinomycin A, from culture filtrates of an actinomyces, which is almost equally potent. But whereas actinomycin A is extremely toxic to animals, penicillin has little if any toxic effect, even when administered in large doses. Mice weighing 20 gm. tolerated the intravenous injection of 20 mg. of a penicillin preparation containing 325 units per milligram without any noticeable ill effect, while Hobby *et al.* (1942) found the lethal dose for 18 gm. mice to be about 30 mg. of 250 units per milligram sodium salt. This lack of toxicity applies also to much less pure preparations. That none of the impurities is very toxic is an astonishing and particularly fortunate circumstance, for it has made possible the clinical use of penicillin in a crude form without subjecting it to a complicated purification process. Penicillin preparations containing about 100 units per milligram are commonly employed for clinical purposes of all kinds, but most of the early pharmacological and biological studies were carried out with less pure preparations, containing about 40 units per milligram.

After it had been shown that large amounts were harmless when given intravenously, the lack of toxicity to important individual cell types was demonstrated *in vitro*. For example, suspensions of leucocytes tolerated a 1 in 1,000 solution of material of 40 units (which inhibited the growth of staphylococci at a dilution of 1 in 1 million) and later were found to tolerate a 1 per cent. solution of material of 250 units per milligram (which inhibited the growth of staphylococci at 1 in 25 millions). The significance of this fact will be appreciated when it is realized that the body deals largely with infecting organisms by means of the leucocytes—mobile allies which ingest and kill the bacteria. These experiments demonstrated further the important point that with increasing purification toxicity was reduced. Another demonstration of the non-toxicity of penicillin preparations (in this case containing about 40 units per milligram) was furnished by tissue culture studies, undertaken by Dr P. Medawar and Dr F. Jacobi. Fibroblasts, epithelial cells, and monocytes were capable of growth after they had been immersed for 48 hours in a 1 in 2,000 solution. In a number of pharmacological experiments it was established that penicillin had no effect on the blood-pressure, heart-beat, or respiration of cats when given in doses sufficient to produce an antibacterial concentration in the blood. It could be injected directly into the brain and cerebrospinal fluid of rabbits without toxic symptoms.

An important question was whether penicillin was destroyed in the body or by the tissue

TABLE I

DILUTIONS OF PENICILLIN AT WHICH VARIOUS INHIBITORY EFFECTS HAVE BEEN OBSERVED

(From Abraham *et al.*, 1941)

| Bacterial species | No. of strains | Dilutions at which inhibitory effects were observed | | | Notes |
|---|---|---|---|---|---|
| | | Complete | Partial | None | |
| *N. gonorrhoeae*[1] .. .. | 6 | 2,000,000 | >2,000,000 | >2,000,000 | — |
| *N. meningitidis* .. .. | 1 | 1,000,000 | 2,000,000 | 4,000,000 | — |
| *Staph. aureus* .. .. | 4 | 1,000,000 | 2,000,000 | 4,000,000 | — |
| *Strep. pyogenes* .. .. | 3 | 1,000,000 | 2,000,000 | 4,000,000 | — |
| *B. anthracis* .. .. .. | 1 | 1,000,000 | 2,000,000 | 4,000,000 | — |
| *A. bovis* (*hominis*) .. .. | 1 | 1,000,000 | 2,000,000 | 4,000,000 | Deep glucose-agar shake cultures. |
| *Cl. tetani*[2] .. .. .. | 1 | 1,000,000 | — | — | Limit not observed. |
| *Cl. welchii* .. .. .. | 1 | 1,500,000 | — | — | Limit not observed. |
| *Cl. septique* .. .. .. | 1 | 300,000 | 1,500,000 | 7,500,000 | Fivefold dilutions used. |
| *Cl. oedematiens* .. .. | 1 | 300,000 | — | 1,500,000 | Inoculum of spores. |
| *Strep. viridans*[3] .. .. | 2 | 625,000 | — | 3,125,000 | But see other strains below. |
| *Pneumococcus*[3] .. .. | 6 | 250,000 | 500,000 | 1,000,000 | 3 of type 1; one each of types 3, 7, and 9. Some complete at 500,000. |
| *C. diphtheriae* (*mitis*) .. | 1 | 125,000 | — | 625,000 | Intermediate dilutions not tested. |
| *C. diphtheriae* (*gravis*) .. | 1 | 32,000 | 64,000 | 128,000 | — |
| *S. gärtneri* .. .. .. | 1 | 20,000 | 40,000 | 80,000 | — |
| *S. typhi* .. .. .. | 2 | 10,000 | 30,000 | 90,000 | Higher of two results shown. |
| *Pneumococcus*[3] .. .. | 3 | 9,000 | — | 27,000 | Types 1, 7, and 19. |
| Anaërobic streptococcus[3] | 1 | 4,000 | 8,000 | 16,000 | — |
| *Proteus* .. .. .. | 3 | 4,000 | 32,000 | 60,000 | Best strain shown. Others 4 times less sensitive. |
| *Strep. viridans*[3] .. .. | 1 | 4,000 | 8,000 | 16,000 | — |
| *Past. pestis* .. .. .. | 2 | 1,000 | 100,000 | 500,000 | Partial inhibition between 1,000 and 100,000 |
| *S. typhimurium* .. .. | 1 | < 1,000 | 8,000 | 16,000 | Partial 1,000–8,000. |
| *S. paratyphi B* .. .. | 2 | < 1,000 | 5,000 | 10,000 | Partial 1,000–5,000. |
| *Bact. dysenteriae* Shiga .. | 1 | 2,000 | 4,000 | 8,000 | — |
| *Br. abortus* .. .. .. | 1 | 2,000 | 4,000 | 8,000 | — |
| *Br. melitensis* .. .. | 1 | < 1,000 | 2,500 | 10,000 | — |
| Anaërobic streptococcus.. | 1 | < 4,000 | < 4,000 | 4,000 | — |
| *V. cholerae* .. .. .. | 1 | < 1,000 | 1,000 | 2,000 | — |
| *Bact. coli* .. .. .. | 5 | < 1,000 | < 1,000 | 1,000 | One strain showed complete 200, none 400. |
| *B. friedländeri* .. .. | 1 | < 1,000 | < 1,000 | 1,000 | — |
| *Ps. pyocyanea* .. .. | 2 | < 1,000 | < 1,000 | 1,000 | — |
| *Myco. tuberculosis* .. .. | 1 | < 1,000 | < 1,000 | 1,000 | See text. |
| *L. icterohaemorrhagiae* .. | 1 | < 3,600 | < 3,600 | 3,600 | Lower dilutions not tested. |

[1]Another strain was inhibited only up to 32,000. [2]Grown in Lemco broth. In beef broth complete inhibition only reached 100,000. [3]In *Pneumococcus*, *Strep. viridans*, and anaërobic streptococci, different strains appear at different levels in the table. [*A.* = *Actinomyces*; *Br.* = *Brucella*; *C.* = *Coryne bacterium*; *Cl.* = *Clostridium*; *L.* = *Leptospira*; *Myco.* = *Mycobacterium*; *N.* = *Neisseria*; *Past.* = *Pasteurella*; *Ps.* = *Pseudomonas*; *S.* = *Salmonella*; *V.* = *Vibrio*.]

constituents. It was found that the antibacterial activity was in no way diminished by blood, pus, tissue autolysates, or protein hydrolysates. Penicillin was to a large extent excreted rapidly by the kidneys, which indicated that relatively little destruction had occurred in the body.

The antibacterial activity of penicillin within wide limits was not influenced by the number of bacteria present. This fact and its insensitivity to the products of tissue decomposition give penicillin important advantages over the sulphonamide drugs, which do not act effectively in the presence of protein breakdown products or if large numbers of bacteria are present.

Penicillin even in strong solutions does not kill bacteria immediately, but merely inhibits their

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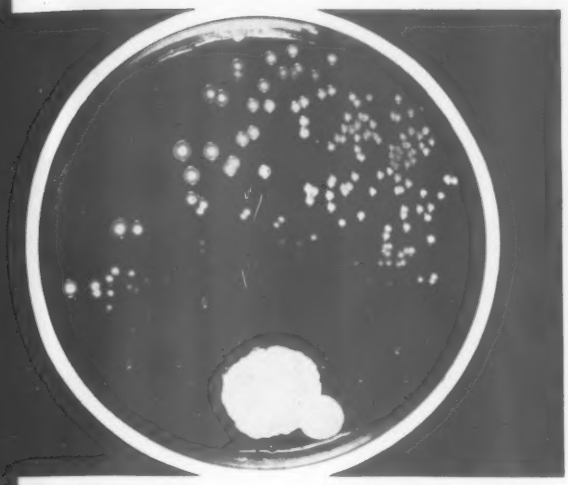


RE 1 – *This is Fleming's original plate with the mould con-ant. From descendants of this mould all the penicillin in the was made until recently. Note how colonies of staphylococci isappearing in the neighbourhood of the mould.*

FIGURE 2 – *Colonies of* Penicillium notatum *growing on nutrient agar. (Enlarged* $1\frac{1}{2}$ *times.)*

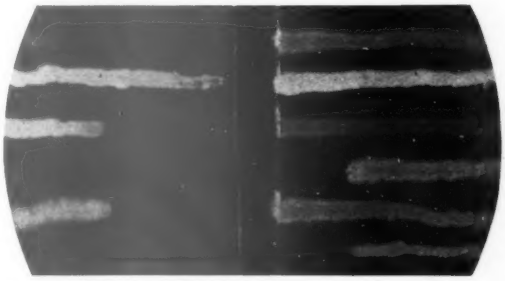
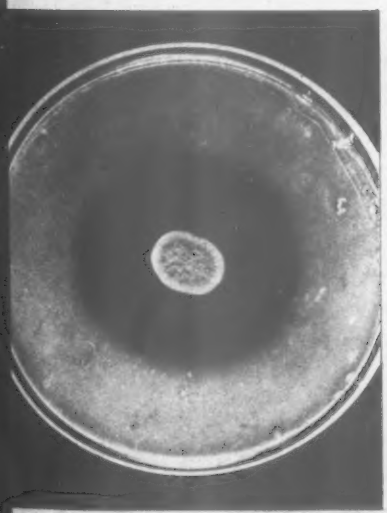



FIGURE 3 – *A 'gutter plate' prepared by Fleming's method. A gutter is cut in a nutrient agar plate and the gutter then filled with melted agar containing penicillin. The penicillin diffuses from this strip a certain distance into the rest of the agar. Various species of bacteria are planted on the agar in streaks. Those which are not sensitive to penicillin grow right up to the gutter. Those which are sensitive are prevented from growing where the penicillin has diffused and so do not grow right up to the gutter.*



RE 4 – *A culture of* Penicillium notatum *re) on nutrient agar. After a few days' growth gar plate was heavily seeded with staphyl-. There is a clear zone around the mould the staphylococci have not grown.*

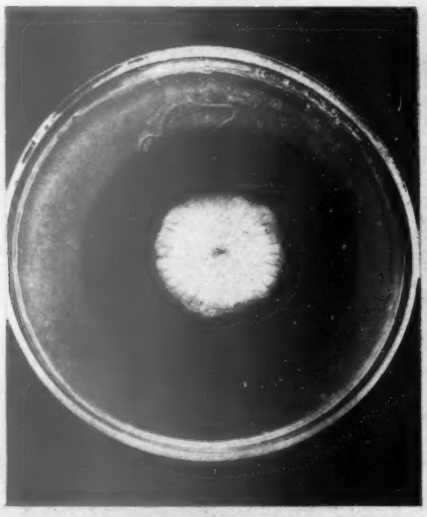


FIGURE 5 – *A culture of* Aspergillus giganteus *treated in a similar way to figure* 4. *This mould produces a penicillin-like substance.*

FIGURE 6 – *A culture of* Penicillium cyclopium *treated in a similar way to figure* 4. *This mould produces penicillic acid (not related in any way to penicillin), which is toxic.*

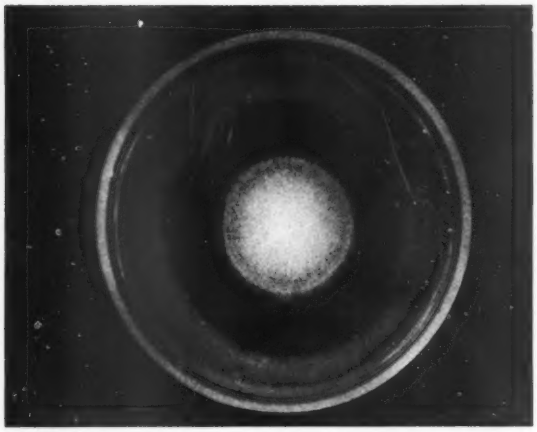


FIGURE 7 – *A culture of* Aspergillus terreus *treated in a similar way to figure* 4. *This mould produces terreic acid, which is toxic.*

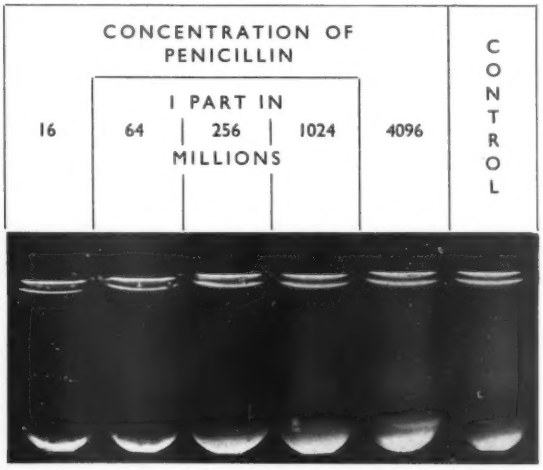



FIGURE 8 – *Serial dilutions of penicillin in broth containing staphylococci. Growth of the bacteria in the tubes on the left has been suppressed by penicillin. This method can be used for assay purposes.*

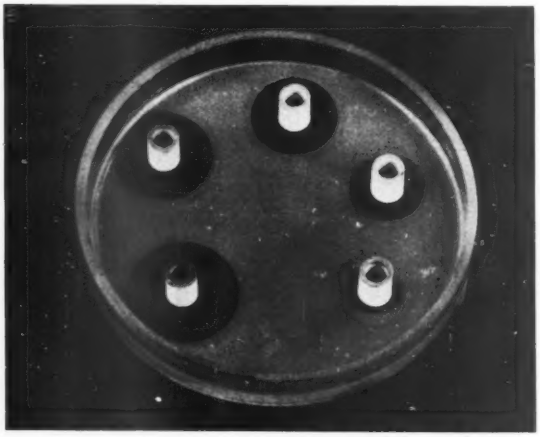


FIGURE 9 – *Heatley's assay method. Cylinders of porcelain are placed on the surface of an agar culture medium which has been heavily sown with staphylococci. Penicillin solutions are placed in the cylinders and diffuse into the agar, causing an inhibition of bacterial growth. The size of the circular zone of inhibition bears a relationship to the amount of penicillin present.*

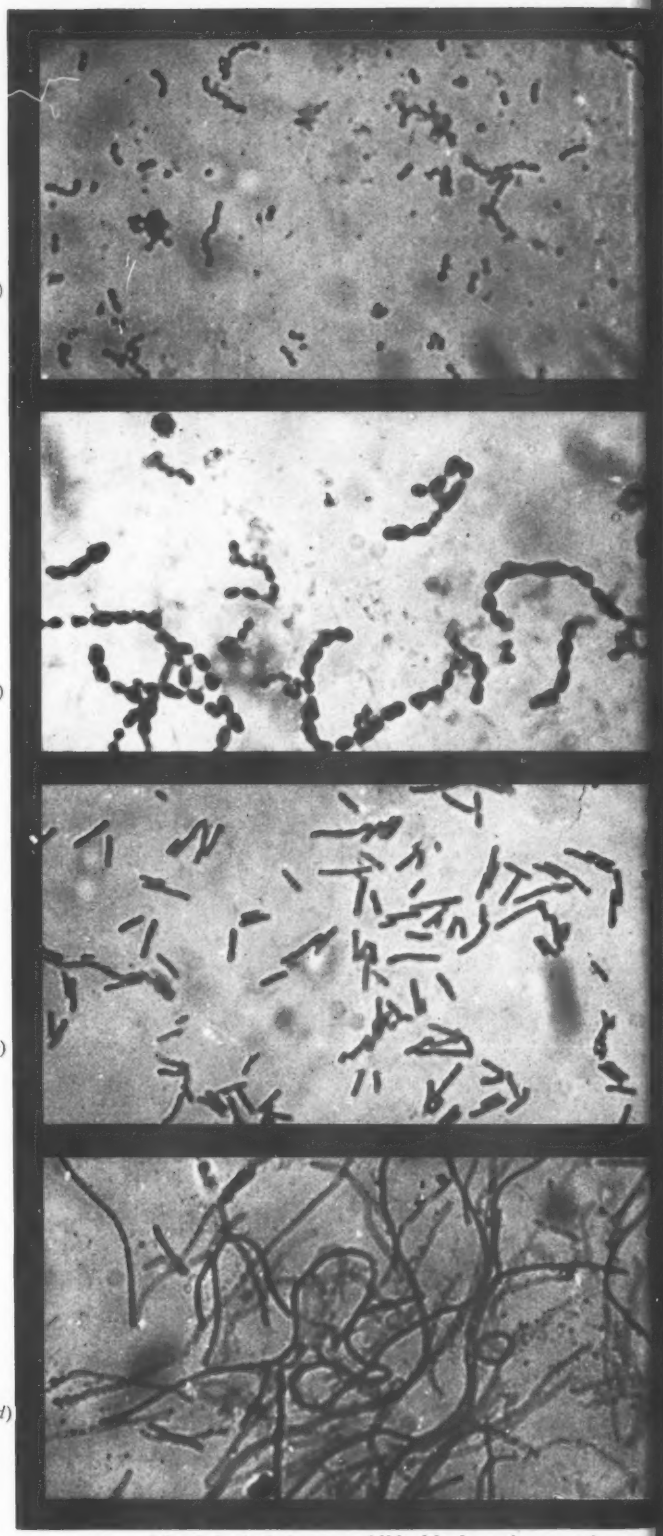



FIGURE 10 – *Morphological changes exhibited by bacteria grown in a stre of penicillin not sufficient to stop all growth. Giant forms are produced, a readily be seen from comparison with the untreated bacteria.*

(*a*) *Normal streptococci.* ( ×1,000.)
(*b*) *Penicillin-treated streptococci.* (*Same magnification.*)
(*c*) *Normal typhoid bacilli.* (×1,000.)
(*d*) *Penicillin-treated typhoid bacilli.* (*Same magnification.*)

(*We are indebted to Dr M. A. Jennings for the preparations, and to Dr A. G. Sanders and Mr H. for the photographs.*)

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growth. This was established by demonstrating that the respiration of staphylococci remained unaffected by a strong solution over many hours, as well as by the usual bacteriological methods. One may conceive that the main action of penicillin against bacteria in the animal body is to inhibit multiplication of the organisms. This has an important corollary in clinical application, in that measures must be taken to keep penicillin in contact with the organisms for a sufficient length of time to enable the leucocytes to do their work. Precisely how penicillin interferes with bacterial division has not yet been determined. An interesting phenomenon (Gardner, 1940) associated with the inhibition of bacterial growth was the production of giant forms when susceptible bacteria were grown in a concentration of the drug just insufficient to suppress growth completely. A similar phenomenon was shown by relatively insensitive bacteria, such as the typhoid organism. This is a morphological demonstration of the interference of penicillin with the division mechanism of bacteria (figure 10).

Penicillin was readily absorbed after intramuscular or subcutaneous injection, but not after oral administration, since it was destroyed by the hydrochloric acid of gastric juice. It was, however, absorbed from the small intestine, though not from the colon where, apparently, the bacteria destroyed it. It was excreted into the saliva and bile, but did not pass freely from the blood-stream into the cerebrospinal fluid.

With the establishment of all the above-described biological properties it seemed highly likely that

TABLE II

RESULTS OF THERAPEUTIC TESTS ON MICE INFECTED WITH *Strep. pyogenes, Staph. aureus and Cl. septique*
(From Chain *et al.*, 1940)

| Expt. | — | Dose of infecting culture (ml.) | Interval before starting treatment (hrs.) | Duration of treatment | Single dose (mg.) | Total dose (mg.) | No. of mice | Survivors at end of hours 6 | hours 12 | hours 24 | days 2 | days 3 | days 4 | days 5 | days 6 | days 7 | days 8 | days 9 | days 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Strep. pyogenes*—Lancefield, Gp. A. | | | | | | | | | | | | | | | | | | | |
| 1 | Controls | 0·5 | — | — | — | — | 25 | — | 15 | 9 | 8 | 6 | — | 5 | — | 4 | — | — | 4[1] |
| | Treated | 0·5 | 1 | 12 hrs. | 2 | 10·0 | 50 | — | — | — | 49 | 42 | — | 34 | 30 | 28 | — | 26 | 25 |
| 2 | Controls | 0·5[2] | — | — | — | — | 25 | 24 | 3 | 0[3] | — | — | — | — | — | — | — | — | 0 |
| | Treated | 0·5 | 2 | 45 hrs. | 0·5 | 7·5 | 25 | 24 | — | — | — | — | — | — | — | — | — | — | 24 |
| *Staph. aureus*[4] | | | | | | | | | | | | | | | | | | | |
| 1 | Controls | 1·0 | — | — | — | — | 24 | 21 | 1 | 0[3] | — | — | — | — | — | — | — | — | 0 |
| | Treated | 1·0 | 1 | 55 hrs. | 0·5 | 9·0 | 25 | 25 | 12 | — | 11 | — | 10 | — | — | — | — | — | 8 |
| 2 | Controls | 0·2[2] | — | — | — | — | 24 | 23 | 15 | 5 | 0 | — | — | — | — | — | — | — | 0 |
| | Treated | 0·2 | 1 | 4 days | 0·5 | 11·5 | 24 | — | 23 | 22 | — | — | 21 | — | — | — | — | — | 21 |
| *Cl. septique* | | | | | | | | | | | | | | | | | | | |
| 1 | Controls | See text | — | — | — | — | 25 | — | 21 | 0[5] | — | — | — | — | — | — | — | — | 0 |
| | Treated | — | 1 | 10 days | 0·5 | 19 | 25 | — | — | 24 | 21 | — | 18 | — | — | — | — | — | 18 |
| | | — | 1 | 10 days | 1·0 | 38 | 25 | — | — | — | — | — | 24 | — | — | — | — | — | 24 |

[1] A control mouse which was killed by mistake at 24 hours is counted as a survivor. Heart-blood culture strongly positive.
[2] Between experiments 1 and 2 the virulence of the organism was raised by passage. [3] Controls all dead within 16 hours.
[4] A bovine strain exceptionally virulent to mice kindly supplied by Dr H. J. Parish of the Wellcome Laboratories.
[5] Controls all dead within 17 hours.

penicillin in proper dosage would prove to have outstanding chemotherapeutic properties *in vivo* against susceptible organisms. That this was indeed the case was shown in a series of mouse protection experiments, the results of which are set out in Table II.

These animal experiments demonstrated clearly that penicillin was not only an 'antiseptic,' as Fleming had suggested, but a chemotherapeutic agent likely to be of first importance. The final assessment of its value to medicine depended, however, on whether it could be used for the successful treatment of naturally occurring disease in man.

All work with penicillin has been constantly hampered by the difficulty of procuring enough material, and the step from mouse to man was a large one. Eventually, in the course of some months, enough material was accumulated for a trial on man.

The first injection given was 100 mgm. intravenously of the same material that had been used for the mouse protection experiments (containing about 10 units per milligram). A little over an hour later the patient had a shivering attack and a rise of temperature. Repetitions of the injection gave similar results, so that it was clear that crude penicillin contained some pyrogenic material. It was found that this pyrogenic material could be removed by chromatographic separation. Although the amount of penicillin required for the first two cases with severe infection was underestimated, good indications were obtained of benefit in an infection caused in one case by the staphylococcus and in the other by the streptococcus. Four more cases, two with severe sepsis, were treated with such encouraging results that it became imperative to procure larger quantities of penicillin (Abraham *et al.*, 1941).

Now that most of the difficulties have been overcome it is interesting to look back at that time when most people considered the use of penicillin in therapy impracticable because of its supposed lability, and because of the large volume of culture medium and great labour involved in its preparation. Nevertheless the work was pressed on, and with material partly made in Oxford and partly produced by Imperial Chemical Industries it was possible to treat fifteen cases of severe sepsis, most of them patients who had had every appropriate form of therapy before penicillin was used (Florey and Florey, 1943). During this clinical trial an effective dosage and method of use were worked out, and it is of interest that from a large series of cases recently treated in America the dosage and form of treatment arrived at are practically the same as those originally proposed (Keefer *et al.*, 1943).

Penicillin appears to be a drug with which a striking therapeutic effect can be produced with quantities far below any toxic level. In most cases with new drugs the upper limit is determined by the occurrence of toxic symptoms. For example, in judging the correct dosage of the sulphonamides the aim has been to give as much as possible short of producing a toxic effect. With penicillin the aim has been to give as little as possible owing to the great rarity of the product. There can be little doubt that if penicillin becomes cheap and abundant the doses now given will be considered small, though they are in most cases effective. In treating severe generalized sepsis caused by such organisms as the staphylococcus and streptococcus, penicillin has to be applied to the lesion via the blood-stream, so the drug is administered either by intravenous or by intramuscular injection; but for many septic lesions it is possible to apply solutions or other preparations locally to the infected region, thus effecting a great economy. Methods and dosage for this form of application have been devised (Florey and Florey, 1943; Clark *et al.*, 1943; Bodenham, 1943; Florey, M. E., and Williams, 1944). Local application has been shown in some hundreds of cases to be effective in ridding lesions of susceptible pathogenic organisms, with great consequent benefit to the healing and restoration of function of the infected part. The importance of these observations for the treatment of war wounds, the majority of which are more or less septic, need hardly be stressed.

There is reason to believe that not every infection, even by such an organism as the staphylococcus, may be controllable. It has been found (Abraham *et al.*, 1941) that it is possible to habituate organisms to grow in penicillin. In this way they become penicillin-resistant just as certain streptococci become sulphonamide-resistant and hence not amenable to therapy. This production of penicillin-resistant strains has recently been confirmed (Rammelkamp and Maxon, 1942; McKee and Houck, 1943). Further, a certain number of strains of *Staph. aureus* are naturally resistant. Scott Thomson (1943) has recently shown that these constitute about 4 per cent. of the staphylococci occurring in war wounds. On the other hand, strains of organisms which have become sulphonamide-resistant remain penicillin-sensitive.

The remarkable chemotherapeutic effects which

can be obtained with penicillin in generalized and local infections have now been amply confirmed by American workers (Herrell, 1943; Keefer *et al.*, 1943), and the position may be stated in this way: if an organism is highly sensitive *in vitro* to the action of penicillin, then a curative effect can be obtained *in vivo* if a suitable dose is administered by a proper technique for a sufficient length of time. One possible exception to this is where the heart-valves are infected.

The potentialities of penicillin are great, and one can only wonder at the succession of fortunate happenings attending its discovery and development. Intensive research in the field of antibiotics carried out mostly during the last few years has disclosed none which is not too toxic for general administration. Thus it becomes more and more apparent that penicillin occupies at present a unique position among antibiotics in combining great antibacterial power with very low toxicity. Table III is a selection of antibiotics so far discovered and described.

The only antibiotic, other than penicillin, so far examined which merits attention as a chemotherapeutic agent is helvolic acid. This substance has many desirable properties, such as stability, low toxicity to leucocytes and tissue cultures, and relatively low toxicity following a single intravenous injection, but its prolonged administration results in severe liver damage. Strains of staphylococci naturally resistant to penicillin are quite sensitive to helvolic acid.

It is proper that new and potent drugs should be used at first mainly on late and desperate cases, and such has, in the main, occurred with penicillin used parenterally. Now that its therapeutic effect and lack of toxicity are generally recognized, there should be no difficulty in using the material at the earliest possible moment or, better still, in employing it prophylactically. The only barrier standing in the way of widespread application is the scarcity of the material. Great efforts are being made by commercial firms and others, both in this country and in America, to bring production to a maximum by increasing the yields obtained from culture and by improving extraction methods. Even though large amounts may eventually be produced by this means, it would appear likely that the best prospect of supplying the great need will lie in the synthesis of the active

TABLE III

| *Antibiotic* | *Source* | *Author* | *Organisms affected* |
|---|---|---|---|
| Gramicidin .. .. | *Bacillus brevis* | Dubos, 1939 | Predominantly Gram-positive |
| Actinomycetin .. | *Actinomyces albus* | Gratia and Dath, 1924 | Gram-positive and Gram-negative |
| Actinomycin A and B | *Actinomyces antibioticus* | Waksman and Woodruff, 1941 | Predominantly Gram-positive |
| Proactinomycin .. | *Proactinomyces Gardner* | Gardner and Chain, 1942 | Predominantly Gram-positive |
| Streptothricin .. .. | *Actinomyces lavendulae* | Waksman and Woodruff, 1942 | Gram-positive and Gram-negative |
| Gliotoxin .. .. | *Trichoderma lignorum* | Weindling and Emerson, 1936 | Gram-positive and Gram-negative |
| Penicillic acid .. | *Penicillium puberulum* | Alsberg and Black, 1913 | Gram-positive and Gram-negative |
| | *Penicillium cyclopium* | Oxford, Raistrick and Smith, 1942 | Gram-positive and Gram-negative |
| Claviformin[1] .. .. | *Penicillium claviforme* | Chain, Florey and Jennings, 1942 | Gram-positive and Gram-negative |
| Citrinin .. .. | *Penicillium citrinum* | Raistrick and Smith, 1941 | Predominantly Gram-positive |
| Fumigatin .. .. | *Aspergillus fumigatus* | Oxford, 1942 | Predominantly Gram-positive |
| Fumigacin .. .. | *Aspergillus fumigatus* | Waksman, Horning and Spencer, 1943 | Gram-positive |
| Clavacin .. .. | *Aspergillus clavatus* | Waksman, Horning and Spencer, 1943 | Gram-positive and Gram-negative |
| Aspergillic acid .. | *Aspergillus flavus* | White and Hill, 1943 | Gram-positive and Gram-negative |
| Helvolic acid .. .. | *Aspergillus fumigatus* | Chain, Florey, Jennings and Williams, 1943 | Gram-positive |

[1]Patulin, which has recently been described by Raistrick *et al.* (1943), is identical with claviformin (Chain *et al.*, 1942, 1944; Crowfoot and Low, 1944), and reports about its efficacy in the common cold are conflicting (Stuart-Harris *et al.*, 1943).

material. It can be conceived that if this is accomplished, the production of large numbers of related compounds by chemical manipulation will be possible and, just as the properties of the sulphonamides have been modified, so may those of penicillin. The therapeutic work so far done with very impure penicillin preparations may in a few years be looked upon as the first halting steps towards the discovery of a new range of powerful chemotherapeutic agents.

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# Geology's debt to Henry Thomas de la Beche

F. J. NORTH

Britain was the first country in the world to make an official geological survey of its land, and is still the best and most fully documented in this respect. Most of the credit for the original work is due to Sir Henry Thomas de la Beche, who for some obscure reason has never found a biographer. Dr North, who has had access to many of de la Beche's unpublished letters and diaries, here describes the circumstances in which the Geological Survey was initiated, developed, and grew into a permanent national institution.

The 'Geological Survey' of Great Britain was the first official undertaking of its kind in the world. Directly or indirectly affecting mining, civil engineering, building, water-supply, agriculture, and industry, it has increased our knowledge of the geology of Britain to a greater extent than would have been possible by private enterprise; but published records have very little to say of the circumstances in which it originated.

From *The First Hundred Years of the Geological Survey of Great Britain*, by Sir J. S. Flett (1937), we learn that 'the initiative appears to have come actually from the Ordnance Survey, which applied to Buckland, Sedgwick, and Lyell for a recommendation or report,' and that 'the reason why de la Beche took on the task of colouring Ordnance maps can now only be inferred.'

FIGURE 1 – *Sir H. T. de la Beche, C.B., F.R.S.* (*From a portrait in the* Illustrated London News, *17th May, 1851.*)

The first of these statements is a reasonable interpretation of remarks by certain presidents of the Geological Society of London. In 1834 G. B. Greenough reported that:

> Mr de la Beche, . . . acting under the direction of the Board of Ordnance, has produced a geological map of the county of Devon. . . . Let us rejoice in the success which has attended this first attempt of that Honourable Board to exalt the character of English topography by rendering it . . . more scientific.

Two years later Charles Lyell said:

> . . . An application was made by the Master General and Board of Ordnance, to Dr Buckland and Mr Sedgwick as professors of Geology in the Universities of Oxford and Cambridge, and to myself as President of this Society, to offer our opinion as to the expediency of combining a geological examination of the English counties with the geographical survey now in progress. In compliance with this requisition we drew up a joint report . . .

It is sufficient here to note that the report was favourable, and that Lyell concluded his reference to it by saying: 'I congratulate the Society that Mr de la Beche has been chosen to discharge an office for which he is so eminently qualified.'

de la Beche (1796–1855), almost alone amongst his peers and contemporaries in the geological world, has never been the subject of a biography, and search for material that might be used to remedy this deficiency has brought to light a large number of unpublished letters and diaries[1]. Some of these relate to proposals he made for geologically colouring certain Ordnance Survey maps, and show that the

[1] Most of these were kindly placed at my disposal by the late Colonel J. I. D. Nicholl of Merthyr Mawr, and Mr R. M. Dillwyn of Castle-upon-Allum, de la Beche's great-grandsons, and by the Director-General of the Ordnance Survey.

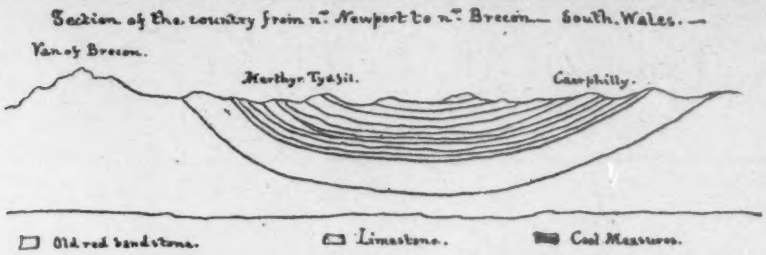



FIGURE 2—*A drawing from one of de la Beche's early notebooks* (1819). *This is the earliest known geological section across the South Wales coalfield, and is comparable to a generalized section that might be drawn today to illustrate an elementary text-book.*

Geological Survey had its origin in his perspicacity and owes its development to his administrative skill. The story provides another illustration of the debt we owe to the pioneers who helped to lay the foundations of the practical applications of science.

As a youth de la Beche entered the Military College at Marlow, but the peace in Europe at the close of the Peninsular War made him give up his military career, and, as he lived at Lyme Regis, in a region full of geological interest, his liking for outdoor occupation led him to collect rocks and fossils and to study the problems of their distribution. Deriving his income from an estate in Jamaica, he shared in the criticism directed against slave-owners, but in the West Indies he was disliked because he was genuinely interested in the welfare of his negroes. He would not, for example, allow his 'drivers' to carry whips, and finding that the officially appointed clergy did very little for the negroes, he arranged for a Wesleyan missionary to give religious instruction to those on his own estate, and refused to admit the legality of the High Commissioner's contention that he should have obtained the 'consent of the quarter session' before doing so.

Labour troubles in the early eighteen-twenties, when he visited the island, were sufficiently serious to make him write:

> Much as I desire speedily to return to my native cool land, the present depressed state of West Indian affairs has so diminished my command of the needful that I cannot exactly state when that may be.

Conditions grew steadily worse after his return to England, and in March 1832, not wanting to abandon a scheme for preparing a geological map of Devon, he asked for assistance from the Master General of the Board of Ordnance. He described the undertaking as:

> one that I had set out with the intention of accomplishing at my own proper cost, but in which I am defeated by the failure of certain funds I had intended to apply to that purpose. I am induced therefore to offer to your Honble. Board the fruits of my labours at a price that I am well assured will be considered very moderate . . .

The memorandum was long, but the essential proposals are worth quoting just as he made them:

> For the sum of £300, I undertake . . . accurately to determine the Geological structure of the district comprised within the eight sheets [of the Ordnance Map] specified, and to lay down the detail accurately to scale . . . in so clear and intelligible a manner as to admit of its being readily transferred to the Ordnance Copper Plates. I will also attach to the margin of each sheet an Index scale of colours descriptive of the rocks and beds comprised within it . . .

He proposed an adjustment in the price of the sheets to cover the cost of adding the geological particulars, and gave a detailed estimate of the profit the Board could expect to make on the transactions, viz. £92 9s.

The proposal was referred to Lieutenant-Colonel Colby (then in charge of the Ordnance Survey). Colby had already displayed an interest in geology to the extent of permitting two of his assistants to make geological observations in the areas in which they were working, and in 1830 had issued a circular to his officers, outlining a 'System of Indicoclature' to be used in 'Geological Plans and Sections.' This contained twenty-five symbols and eight colours; but they related to kinds of rock (e.g. granite, porphyry, limestone), and not to their relative ages. 'Sands of the Chalk' were, for example, represented by the same colour as 'Sands of the Oolite,' and 'Coal Grit' by the same colour as 'Old Red Sandstone,' so that their use could not have resulted in a geological map as we now understand it, and as de la Beche envisaged it.

In his report Colby said:

> . . . Though I object to undertaking any responsibility for the accuracy of the Geological information, and also to any increase of price in the sheets containing the Maps of Devon, I have to report my opinion that the offer made by Mr de la Beche is highly advantageous to the Public.

He expressed doubt whether there would be any profit, but thought that the advantage of

making the Ordnance Survey maps into 'perfect illustrations of the geological features of the country' would outweigh any financial considerations. Five weeks later de la Beche was informed that his proposal had been accepted, and the correspondence which followed illustrates the way in which he handled the varying and often difficult situations that arose before his scheme was finally launched.

> I cannot avoid (he wrote) expressing my fears that one of these conditions, though excellent in theory, will not be found to work in practice; I allude to that which makes it incumbent on us to use no other colours . . . than those which have received the sanction of the Council of the Geological Society. Now if that Council was composed of men who understood the subject and were men of business and dispatch, nothing would be so easy as to have a speedy decision. . . . Unfortunately, however, this is not the case, and we have to arrange with a body, which, with the exception of Mr Greenough and myself, are far from having given the subject proper attention, and as for business and dispatch we must expect little from them. . . .
>
> There seems no chance of determining the colours in the Council of the Geological Society for the present, and I am sadly afraid when they do determine them that they will not by any means be such as will reflect credit on the work, in as much as they will be settled by men who . . . would never have produced a decent Geological Map to accompany any of their memoirs, if it had not been for Gardner of Regent Street, who must have had the patience of Job to get through the work.

Already de la Beche had visions of a larger scheme than the one then under discussion, because in the same letter he said:

> If publication . . . is to be delayed by these worthies of the Geological Society it will cut sadly into the calculations I have entered into as to the pecuniary advantages which the Ordnance may receive from the sale of these Geologically coloured Maps . . . and may prevent the Board of Ordnance from having anything further to do with the Matter than these 8 sheets. . . . This if possible should be avoided.

Colby was as anxious as de la Beche to avoid delay, and suggested that:

> Any colours you think best can be used on the original manuscripts of the Geology, and when we have engraved the lines . . . on the Copper, a Copy can be coloured according to the decision of the Council.

The colour scheme was finally decided upon in consultation with Mr (afterwards Sir) Francis Chantrey.

When reporting early in 1835 that the eight sheets had been completed, de la Beche again raised the question of a more extensive survey:

> I respectfully request that the Honble. Board will be pleased to examine the result of my labors: and if they shall find it desirable . . . I will willingly devote my time to the Geological examination of another portion of the country.

The Board decided to obtain expert opinion, and ordered that the work which Mr de la Beche has completed be referred to the President of the Geological Society, Dr Buckland and Professor Sedgwick, for their Report thereon, the Board being desirous of obtaining the best information the Country can afford before they come to any decision as to the extension of Mr de la Beche's labours. . . .

The report was lengthy but favourable, and included the following passages:

> We regard its [the map's] publication as reflecting great honour on the Board of Ordnance, with whom it originated, and at the same time a benefit to European Science.
>
> We are further of opinion . . . that it would be highly useful to the Nation to continue his [de la Beche's] services, in the extension of a geological survey on one uniform system over other parts of Great Britain.

When Colby had also reported favourably upon the new proposals the Board asked the Treasury for 'Authority to carry into effect the suggestions of the learned Professors . . . that the services of Mr de la Beche may be forthwith secured to the Department.'

Although friendly, the Treasury was cautious:

> The Lords Commissioners . . . (it said) are well aware of the advantage with which such a labor

FIGURE 3 – *A sketch from one of de la Beche's notebooks* (1829). *For several years before suggesting that the maps of the Ordnance Survey should be geologically coloured, de la Beche travelled at home and abroad making geological observations, and his notebooks illustrate his keen perception and his skill in recording what he saw.*

could be undertaken . . .; before however they can give their final consent, . . . my Lords desire you will move the Master General and Board of Ordnance to furnish them with some estimate of the time which they consider will be required for the entire completion of the whole undertaking.

de la Beche's reply was characteristically diplomatic: '. . . I beg to state that I consider that the Geological Map will keep pace with the Geographical Map, and consequently that both Maps will be completed at the same time.'

The Treasury, however, wanted something more definite than that. If, it asked, the completion of the Geological Survey is dependent upon the 'progress of the Geographical Survey,' how long is the latter expected to take?

After further consideration, it was reported that, calculating on the basis of the Devon maps, it would take 21 years to complete the part of England and Wales of which the Ordnance maps were already published:

If, however, he received the aid of two or three competent assistants, Mr de la Beche considers that he would complete the part in 7 years. Estimating the rate of progress as above, . . . the Geological Map of England and Wales may be completed in about 10 years.

Permission to continue the work having been given, de la Beche went to Cornwall (on a salary of £500 per annum) and within a week we find him writing to the Chancellor of the Exchequer (Mr Spring Rice), proposing an additional activity:

I beg respectfully to suggest, as the persons employed on the Geological Survey will have constant opportunities afforded them of collecting specimens illustrative of the applications of Geology to the useful purposes of life, that a collection of these specimens be placed in a room or rooms under the care of the Board of Public Works.

He amplified this suggestion in letters to the Office of Woods, and to Colby he wrote: 'I expect daily to hear from the Board respecting the Museum to exhibit the mineral wealth of the country. This is a matter which I have much at heart.'

About a month later he was informed that his plans were to be adopted, and that a house in Craig's Court [Charing Cross], London, was to be used for the purpose. In the following year he was able to report that: 'The specimens in the Museum are all labelled and the localities where they were obtained are properly marked on them.'

It was called the Museum of Economic Geology, and from it sprang first the Museum of Practical Geology in Jermyn Street, and then the Geological Museum at South Kensington.

So much for the inception of the Geological Survey and Museum; their successful development was due to de la Beche's determination not to be deflected from his purpose. A request for the establishment of a fully staffed and fully equipped organization would certainly have been refused, but little by little he cajoled or demanded

FIGURE 4 – *A sketch from one of de la Beche's early notebooks* (1819). *He recorded the personal aspects of his travels as well as their scientific results, and his notebooks contain many illustrations of contemporary modes of travel; this one depicts himself and his servant 'geologizing' in the Alps.*

as circumstances dictated, and, ably backed by Colby, who all along took a keen personal interest in the matter, he eventually got what he wanted.

In 1837, after receiving permission to transfer his attention from Cornwall to South Wales, de la Beche pointed out that his salary did not cover the expenses of the Survey on account of the

> constant system of movement which the service requires, and my necessary residence during the greater part of the year at Inns. . . . As I am quite certain it was never contemplated that the discharge of my duties should entail expenses beyond those which my salary would cover, perhaps you would have the goodness to mention the circumstances to the Master General and Board for their consideration. I look for nothing beyond the payment of necessary expenditure, and if £25 per quarter be allowed in lieu of travelling expenses, I will take the risk of such addition being sufficient to cover all expenses.

The Inspector-General of Fortifications did not view this request with favour. To him it 'appeared to be only granting, under the head of a travelling allowance, an addition of £100 a year to Mr de la Beche's agreement, which, if proper, should have been included in the first agreement,' but later he supported it because he supposed that 'a compliance with his request will expedite the publication, and therefore some saving may be expected by the earlier completion of the whole, when the salary would cease.' He naïvely assumed that the Geological Survey would automatically cease to exist as soon as the last sheet of the Ordnance map had been geologically coloured for the first time.

The correspondence, not altogether friendly on the part of the authorities, dragged on for eleven months. de la Beche firmly but respectfully upheld his claim, and at last was informed that 'although it is not strictly in conformity to precedent, £25 per quarter shall be allowed you to cover all travelling expenses without requiring the production of vouchers.' It took five weeks for the authorities to accept the proposal to colour the Devonshire maps, about the same time for them to agree to the extension of the work into Cornwall, a month to inaugurate a Museum of Economic Geology, but a year to settle a routine matter involving an expenditure of £25 per quarter!

When he wanted assistants, de la Beche asked first for a miner to help in the rough work, then for a person who could be trained in geological methods, and, having got the principle established, it was only a matter of time before he had gathered around him a small band of workers as enthusiastic as himself.

In 1839, realizing that he would not be able to complete the map of England and Wales in 10 years as he had supposed, he asked for permission to 'hire such geological assistants as I may consider requisite for the proper execution of the work.' When this request came to the notice of the Inspector-General of Fortifications his comment was: 'I know of no authority for the extensive view here taken of extending the Geological Research,' and he advised that nothing should be done until 'an appropriate estimate of the whole intended outlay' had been obtained. The result was that the Board of Ordnance expressed itself as being

> decidedly of opinion that it will never do to go on with this Geological Survey without some distinct rules by which the expense is to be governed. . . . By reference to the original arrangement it will be seen that a most material departure has already taken place from what was then proposed, and . . . what is now asked for will lead to an unlimited expenditure of time and money.

Asked to indicate how long the whole work would take, and how much it would cost, de la Beche said it was not possible to estimate 'the cost of Geological Surveys and the time necessary for their completion, as until some examination of a given area has been effected, no correct idea of the whole expenditure can be formed.'

Careful handling of the situation eventually resulted in an acknowledgment that it was not possible to foresee and to legislate for every contingency that was likely to arise, and at last Colby was informed that

> the only plan . . . will be, from year to year, to take such a sum as may be deemed advisable, upon which point the Master General and Board would from time to time avail themselves of your opinion and so check any extraordinary expense that may be proposed.

de la Beche was quick to act upon the recommendation, for in less than a month he was able to tell Colby: 'I have picked up one very clever hand as an assistant at 7/- per day, a regular good one he is, and I am now on the look out for others.'

The 'Return' for September 1839 contained two names, and in December the estimates for 1840 provided for *four* assistants. The question of a limit to the duration of the work was never raised again—the Geological Survey had become a permanent institution.

# The coloration of butterflies and moths

G. D. HALE CARPENTER

Many species of Lepidoptera display close similarity to dead leaves, the resemblance often reaching a perfection of detail. Other species flaunt gaudy colours and appear to invite attention. Professor Hale Carpenter sets down some arresting facts concerning both types, and illustrates his article with examples of remarkable interest and beauty.

Coloration implies two ideas: the presence of pigment whose selective absorption of light results in colours which reach the eye, and the distribution of pigments to form pattern. Butterflies and moths, usually considered as creatures of sunlight or darkness, depend for their safety quite as much upon pattern as upon colour; not one is quite uniformly coloured.

Pigments differ in their durability under light, and Plate I reveals some striking facts. Collections long exposed to light show fading to different degrees; many butterflies fade little, and this also applies to day-flying moths; it would seem that they have been fitted with durable dress. But moths which hide during the day and fly only in darkness have pigments ill adapted for exposure, which show fading markedly. It will be noticed that pink or red tints are especially labile, and that the tawny orange colour, such as is shown by our Fritillary butterflies, is very durable: in figure 2 it has survived exposure better than the blackish melanins surrounding it. Very similar tints in butterflies may be produced by pigments of quite different chemical constitution (e.g. figures 25 and 27, or 26 and 30), an example of the widespread circumstance that Nature obtains similar results by very different means.

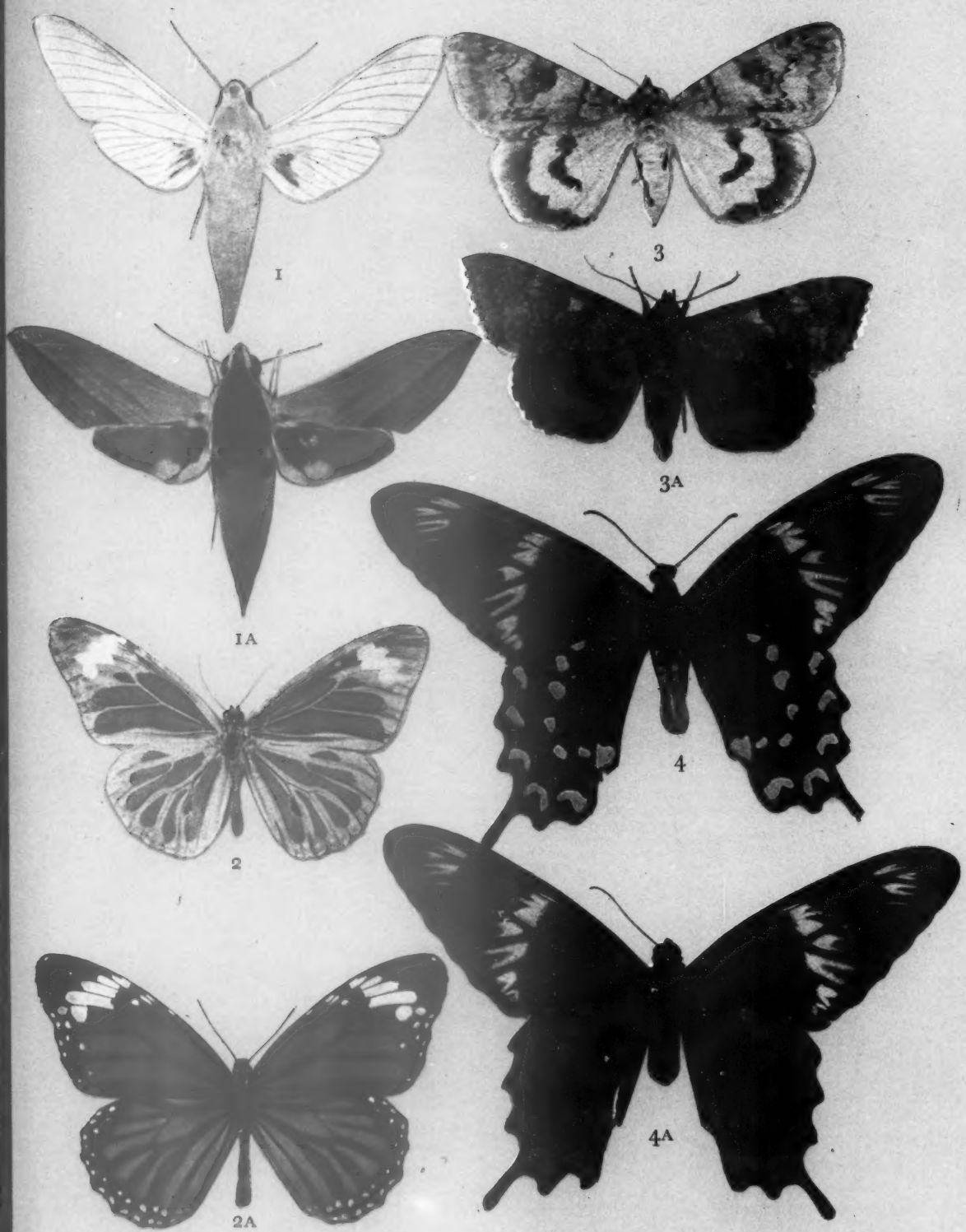
Butterflies and moths when at rest are often concealed by resemblance to dead leaves; these offer an immense variety of shades and patterns. Such species as *Kallima inachus* (figures 7, 10, 11, 13), by resembling a variety of leaves rather than one pattern, make it more difficult for a searching enemy to detect them, and consequently decrease the risk to any particular individual. The perfection of detail extends to the production of an appearance of a ragged or crumpled edge (figures 8, 12) and of discoloration by fungus growth (figures 7, 11). Dead leaves are often slit or holed, letting bright light through; this effect is produced in various species by a notch in the wing (figure 6), by a small area on the wing devoid of scales so that the transparent basal membrane permits the passage of light (figure 11), or by a patch of white pigment which by its brilliance gives the effect of bright light seen through a hole (figures 5, 8).

Objects being recognizable partly by shape, anything which detracts from the regular outline of a butterfly's wing will render it less recognizable. Such a type of coloration, shown in figure 9, is termed disruptive. The strong contrast between light and dark distracts the eye and masks the usual contour by which the outline of the butterfly is perceived.

The great majority of butterflies and moths are so coloured that, when at rest, they are concealed. This applies particularly to the *under* surface of the wings of butterflies, which alone shows when the insect is in complete repose. These cryptically coloured insects are generally edible by vertebrate enemies.

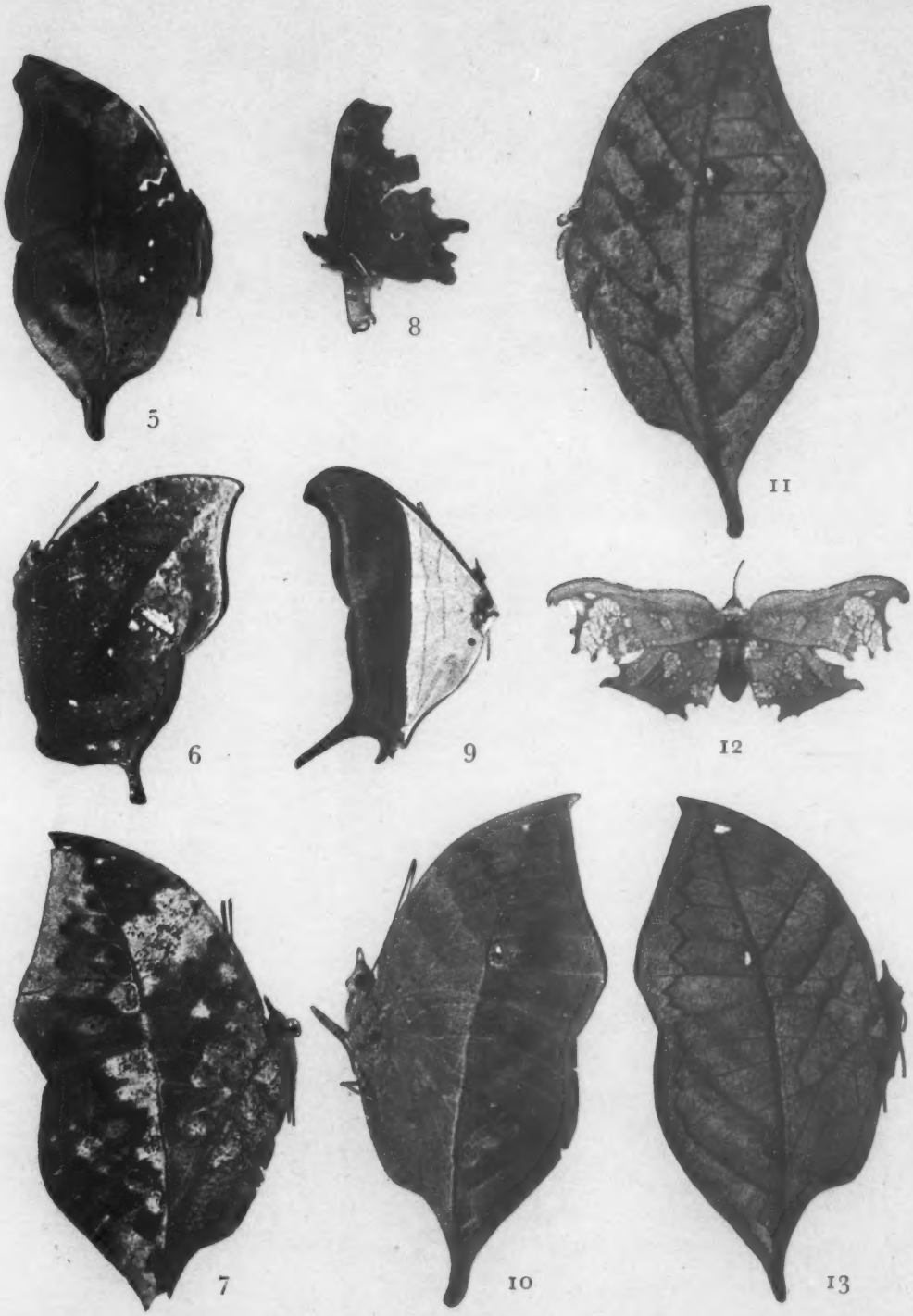
Others, however, flaunt gaudy colours before an observer, seeming to invite attention: these are said to be aposematic, or warningly coloured. The explanation is found in the association with such colours of tough bodily structure, emission of acrid odour, or even violent ejection of strong-smelling fluid which may be displayed as brightly coloured froth by a special attitude. The edibility of such aposematic species is of low degree and, provided there is an abundance of other, more edible, species to provide food they will be left alone. This avoidance of relatively distasteful species, however, must be based on previous experience which necessarily destroys a certain number. Consequently it is to the advantage of a distasteful species to be able to withstand rough handling, through its toughness, so that when released as unfit for food it has not suffered mortal injury. Further, since it is an advantage to such a species to be easily recognized for what it is, the more it facilitates recognition the better for it. As a matter of fact, such types have brilliant colours in simple, strongly contrasted patterns and do not show the beautiful shading and

## PLATE I




Fading of pigments: *Pairs show the effect of prolonged exposure to light in the upper specimen, and a fresh specimen below.* 1 *and* 1A, *Sphingid:* Chaerocampa alecto *L.* (*India*). 2 *and* 2A, *Danaid:* Danaus plexippus *L.* (*India*). 3 *and* 3A, *Noctuid:* Catocala nupta *L.* (*Europe*). 4 *and* 4A, *Papilionid:* Polydorus hector *L.* (*India*).

PLATE II




Cryptic resemblance to dead leaves: *The resemblance produces the effect of a torn leaf* (6, 8), *of fungus growth* (7, 11), *or of damage by a leaf-eating insect* (12). 5, *Nymphalid:* Doleschallia bisaltide *Cramer* (*India*). 6, *Nymphalid:* Anaea morvus *Fabricius* (*Tropical South America*). 7, 10, 11 and 13, *Nymphalid:* Kallima inachus *Boisduval* (*India*). 8, *Nymphalid:* Polygonia *c*-album *L.* (*Europe*). 9, *Nymphalid:* Marpesia coresia *Godart* (*Panama*). 12, *Thyridid:* Draconia rusina *Druce* (*Trinidad*).

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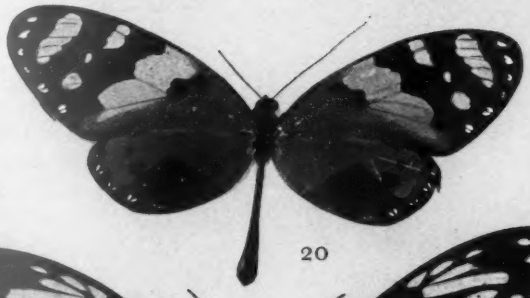

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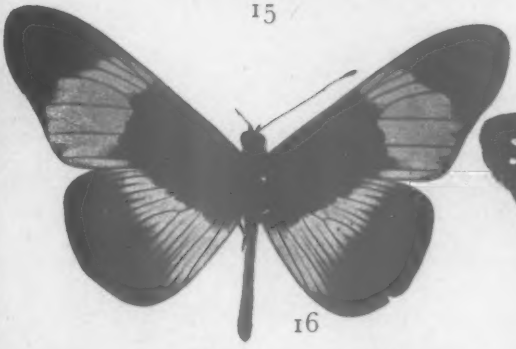

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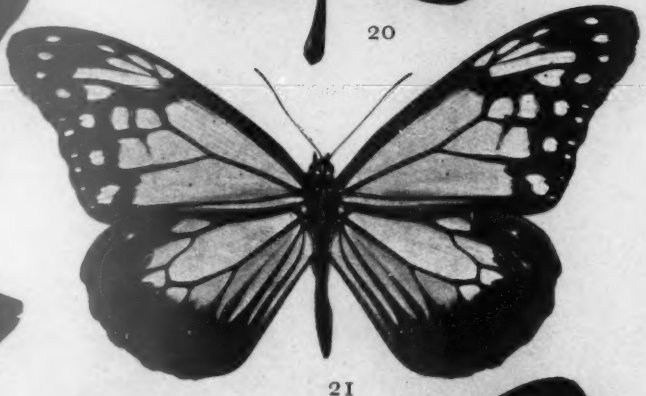

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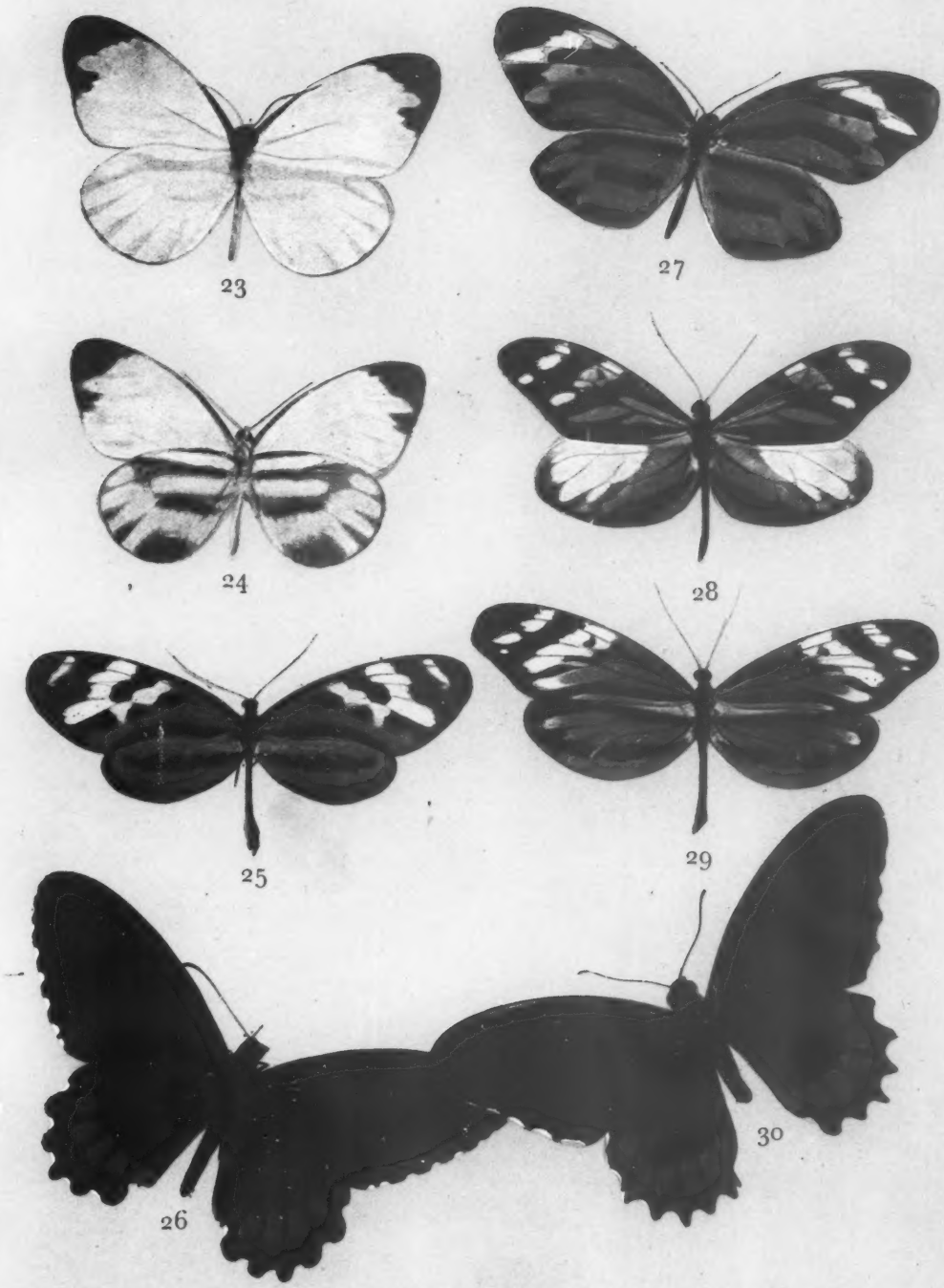
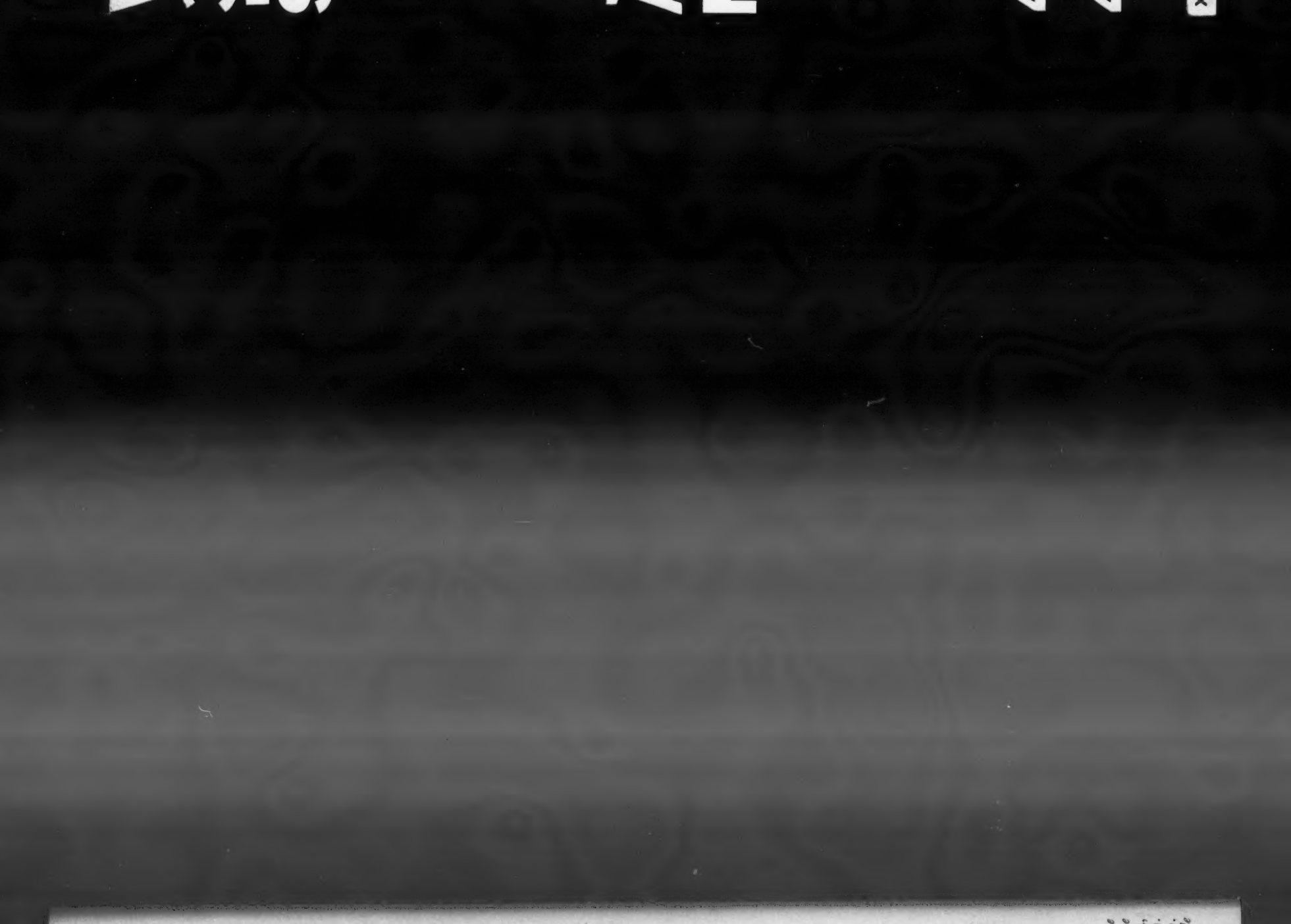
Warning colours: *Butterflies and day-flying moths advertise distastefulness by brilliant colours in simple patterns.* 14, *Pierid:* Delias eucharis *Drury* (*India*). 15, *Heliconid:* Heliconius hydarus *Hewitson* (*Trinidad*). 16, *Acraeid:* Bematistes poggei *Dewitz* (*East Africa*). 17, *Syntomid:* Histioea meldolae *Butler* (*Peru*). 18, *Sarrothripid:* Eligma latepicta *Oberthur* (*Nyasaland*). 19, *Papilionid:* Polydorus hector *L.* (*India*). 20, *Ithomiine:* Melanitis egina *Bates* (*Brazil*). 21, *Danaine:* Danaus sita *Kollar* (*Japan*). 22, *Euploeine:* Euploea leucostictos *Gmelin* (*S.E. Asia*).

PLATE IV




Mimicry: *The distasteful* 25 *is resembled by the female* (27) *of a male* (23), *whose white upper surface is normal for the group to which it belongs: its under surface is shown at* 24. *Mimicry has gone further in another 'White,' of which the female is shown at* 29, *the male at* 28. *Number* 30 *mimics* 26, *belonging to a different section of the family.* 23 *and* 24, *Pierid:* Mylothris malenka *Hewitson, male* (*Venezuela*). 25, *Ithomiine:* Mechanitis veritabilis *Butler* (*Trinidad*). 26, *Papilionid:* Polydorus polyzelus *Felder* (*Guatemala*). 27, *Pierid:* Mylothris malenka *Hewitson, female* (*Venezuela*). 28, *Pierid:* Dismorphia praxinoe *Doubleday, male* (*Trinidad*). 29, *Pierid:* Dismorphia praxinoe *Doubleday, female* (*Trinidad*). 30, *Papilionid:* Graphium belesis *Bates* (*Guatemala*).



complex design of cryptic species (compare Plates II and III). Thus there are two opposing classes of insects—cryptic, with softly shaded dull colours in complex patterns, which find safety in not being discovered; and aposematic, with strongly contrasted brilliant colours which advertise themselves freely as distasteful or even harmful. It is a point of considerable general interest that red and orange are by far the commonest aposematic colours, for the same reason that danger signals and berries are red.

Some aposematic insects, however, are not possessed of the qualities conferring distastefulness, and the associated habits. But so closely, although in superficial appearance only, may they resemble the genuinely aposematic species that they are readily mistaken for them in the field and may be passed over by an enemy not hungry enough to cope with an unpleasant meal. This is the phenomenon of mimicry in its true sense, or pseud-aposematic resemblance, in essence of the same character as resemblance to a stone, bird-dropping, or leaf. One species escapes by resembling an object of no food value; another, an object known to be distasteful. The second class is obviously in some danger, for the protection depends upon the amount of other food available: hence it is rare in Nature. Both types are explicable by the operation of natural selection upon material presented to it by variation.

The female sex in butterflies being intrinsically more variable than the male, it is not surprising that mimicry is more often shown by females (e.g. figures 27 and 29 compared with 23 and 28). Mimicry sometimes seems to have been developed from an initial variation on the under surface (compare figures 24 and 27). The pigment in mimics is often of completely different chemical constitution from that in the models. This is shown well by the 'whites' and their models, and the two 'swallow-tails' (figures 26–30) on Plate IV. The red pigments of the two latter react very differently to simple chemical tests, as shown by E. B. Ford, who has discovered five different types of red pigment in Lepidoptera. This disposes of the facile argument that the similarity in model and mimic may be due to consanguinity.

Very interesting is the case of the African swallow-tail *Papilio dardanus*, which occurs over most of continental Africa south of the Sahara. The male varies little; the female, never like the male, mimics a number of widely different butterflies. In Madagascar, however, the ancestral form occurs with the female much like the male; in both sexes the paler pigment is brilliantly fluorescent in ultra-violet light. This is not so in the mimetic females, in which there has been a chemical change from the ancestral non-mimetic type.

Another kind of polymorphism is seen in countries where there is a great seasonal change in the climate, with a pronounced dry season. Most remarkable results were obtained when naturalists proved by breeding that butterflies of widely different coloration, with important differences of shape and size, were truly the same species. *Precis octavia*, common in Africa, appears in the dry season in an intensely blue form with the under side blackish brown and mottled. During the wet season it is replaced by a smaller, salmon-red, form with the under side of the same colour. *Charaxes zoolina* in the wet season is a greenish white butterfly above and below, with short black bars; in the dry season it is of the russet colour of a dead dried leaf with the under side particularly leaf-like. It will be noted that the dry-season coloration produces more effective concealment when the butterfly is at rest, the time of greatest danger. This is understandable if it be remembered that the dry season is the time of great scarcity of insects, so that there is greater danger to any particular species. But during the wet season with its abundance of food the stress is diminished, and whatever the reason for the bright coloration it has not been countered by natural selection.

Difference in coloration between male and female, or sexual dimorphism, is widespread among butterflies, but there is little direct evidence to account for it. The female, unless mimetic, is usually of more sober colouring, and therefore less conspicuous. In the case of spiders, however, the males in courtship make elaborate use of brightly coloured areas displayed by special attitudes. Dragon-flies show sexual dimorphism to a marked degree, and the writer witnessed in Africa a remarkable display by the brightly coloured male of *Libellago caligata*. The basal segment of each leg is expanded to form a thin surface, brilliantly white anteriorly, scarlet posteriorly. A male was seen courting a dull-coloured female which was sitting on a grass stem: it repeatedly described an arc of a circle in a horizontal plane in front of her, passing from one side to the other, facing her with the legs held so as to display the shining white anterior surface. The red posterior surface would be visible later when the female had been seized by the neck and carried off in the marriage flight.

# Polythene

J. C. SWALLOW

By the polymerization of ethylene under high pressure, a series of new polymeric hydrocarbons of high molecular weight has been produced on an industrial scale. These plastic materials, to which the generic name of polythene has been given, have excellent electrical properties combined with unique physical properties, and are therefore of considerable interest and growing application as dielectrics in the field of electrical engineering.

During the last ten years very great advances have been made in the laboratory synthesis and full-scale production of high molecular weight polymers. Many of these are finding outlets in the electrical industry, the future of which will depend to an increasing extent on the development of new dielectrics in which are combined the chemical, mechanical, and electrical properties necessary for use at the high frequencies and voltages now demanded.

Polythene is a new material now established in this field, and is a product developed by British research. Apart from being produced at pressures higher than those used in any other industrial chemical process at the present time, it is unique in being the simplest synthetic thermoplastic, since it is composed of long methylene chains ($-CH_2-CH_2-CH_2-CH_2-$) of 1,000 units or more. In consequence of its structure it has all the more desirable electrical properties associated with hydrocarbons, such as low dielectric constant, low power loss, and small water absorption, combined with good mechanical properties.

The story of the synthesis of polythene started several years ago in the laboratories of Imperial Chemical Industries, where it was decided to study the effects on chemical reactions of pressures much higher than those hitherto used in chemical industry, the highest pressure employed at that time being 1,000 atmospheres in the synthesis of ammonia.

P. W. Bridgman and other workers had studied the properties of matter up to pressures of 25,000 atmospheres, and the effect of high pressures on chemical reactions had been examined by J. B. Conant and E. Cohen and his school, Conant heaving measured the effect of very high pressures on the rate of polymerization of isoprene, dimethylbutadiene, and styrene.

It was decided, therefore, to carry out experimental work at pressures above 1,000 atmospheres, and the range was later extended to 12,000 atmospheres. In the early work certain selected liquid reactions were studied in small-scale apparatus in which it was possible to measure fairly accurately the effect of pressure on rates of reactions at different temperatures [2], [4], [5], [6]. Later advances in technique made it possible to examine gas reactions at these pressures, and in the course of this work it was found that ethylene could be polymerized to a flexible, tough, crystalline solid with a fairly sharp melting-point of about 110° C.

It was soon discovered that this reaction, which has a very large heat of polymerization, could also result—if the heat of reaction were not adequately dissipated—in an explosive decomposition to carbon and gases. Before further laboratory work could be undertaken, safety devices had to be perfected to protect the investigators and the equipment; and at a very early stage in the work the closest collaboration was necessary between the chemist, the physicist, the metallurgist, and the engineer—who had to produce apparatus which would withstand working pressures of the order of those occurring in a gun. One new device was a self-tightening pressure-joint, known as the wave-ring joint, which proved invaluable in subsequent operating plant. Eventually the novel chemical engineering technique required to enable a continuous process to be operated at the selected working pressure [3] was successfully devised.

Whilst a large number of organic compounds containing the vinyl grouping $CH_2=CH-$ have been polymerized to solids, many of them of great technical importance, yet in the case of ethylene—the simplest of the series—it had not been possible in previous work to obtain anything but oils of short chain-length. Long-chain solid hydrocarbons had been produced by various chemical syntheses such as the decomposition of diazo-methane, the products having a mean

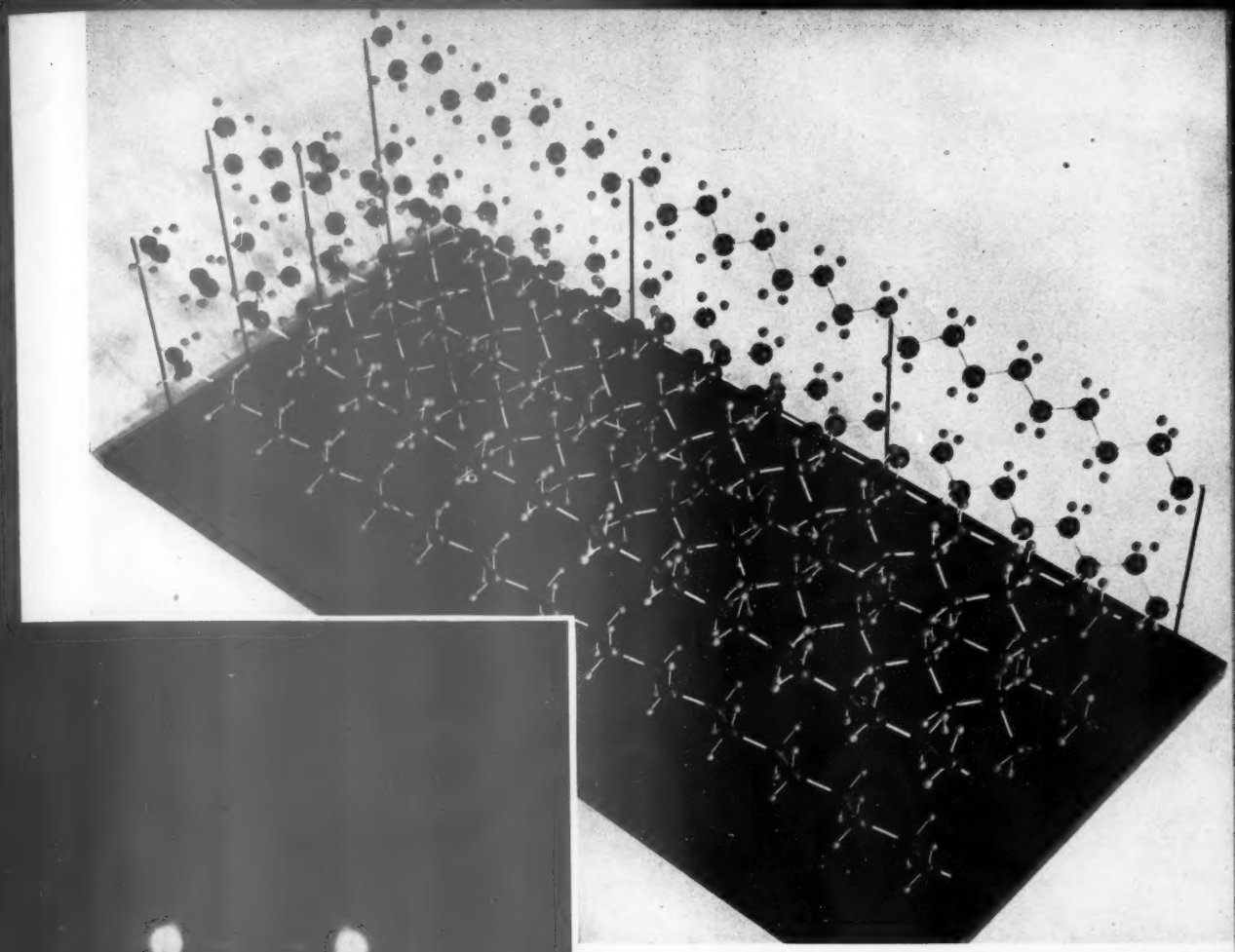
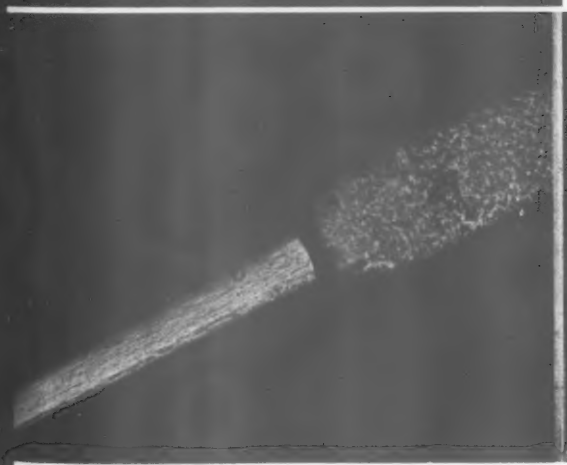


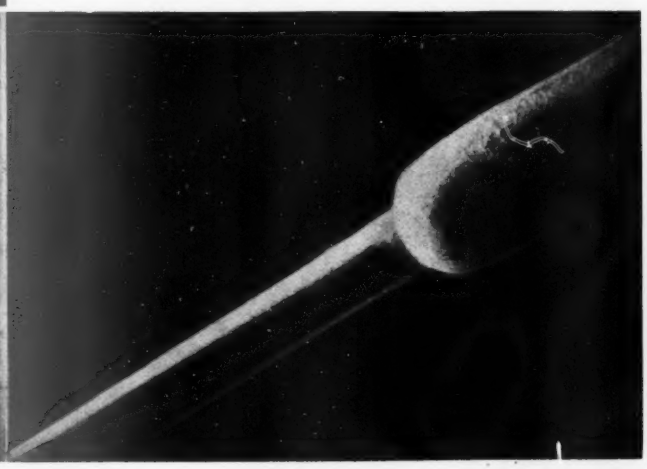
FIGURE 1 (*above*) – *An atomic model of the crystalline fraction of polythene constructed to scale from the results of X-ray determinations.*

FIGURE 2 (*left*) – *X-ray picture of oriented thread showing fibre orientation.*

FIGURE 3 (*bottom, left*) – *Cold drawn fibre between crossed nicols in the 45° position, showing the difference between the oriented and unoriented portions.* (× 80.)

FIGURE 4 (*bottom, right*) – *Cold drawn fibre of polythene—dark ground illumination* (× 80.)





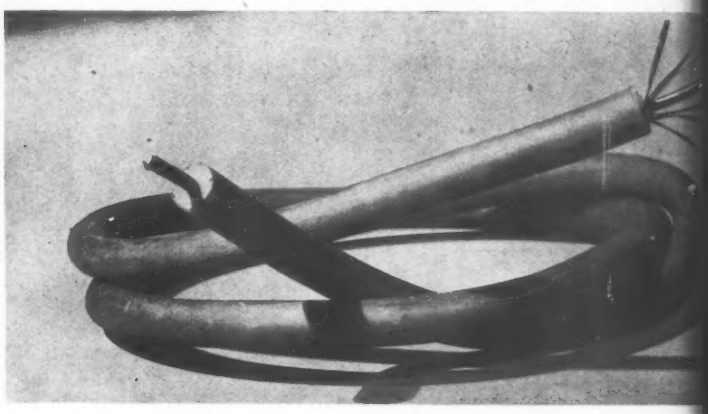


FIGURE 5 (*top, left*) – *A large container made by extrusion moulding normal extrusion machinery.*

FIGURE 6 (*centre, left*) – *Film 3 mils thick made by extrusion.*

FIGURE 7 (*bottom, left*) – *Examples of flawless mouldings and of machined from rod. The smaller examples were made by injection moulding.*

FIGURE 8 (*top, right*) – *Various types of high-frequency cables with poly insulation. The larger cable is protected on the outside by a sheath of plas polyvinyl chloride.* (*Manufactured by Telegraph Construction and Maintenance L*

FIGURE 9 (*centre, right*) – *A submarine cable core insulated with polythene plast with polyisobutylene, which shows the high flexibility.*

FIGURE 10 (*bottom, right*) – *A section through a 440 volt power cable insulate polythene, which has been in service for several years.* (*Manufactured by Johnson and Philipps L*

chain-length of 170 carbon atoms. Products of still higher molecular weight, of the order of 8,000 or more, were obtained by Fischer during the catalytic hydrogenation of carbon monoxide, but all such products were brittle waxes. By the new high-pressure process, therefore, it had been possible to produce the longest unbranched straight-chain hydrocarbon yet made by synthetic methods. Early in the work it was decided to make a detailed examination of the structure by X-ray analysis, and as a result of this it was shown that the product consisted of crystalline regions of orthorhombic symmetry, of unit cell dimensions $a = 7{\cdot}40$ A, $b = 4{\cdot}93$ A, $c = 2{\cdot}53$ A [2]. Figure 1 shows a model of the crystal structure.

The chemical properties of this long-chain hydrocarbon are those which are to be expected from its structure and from its chemical composition, but it is these properties in combination with its mechanical properties which make it of such great technical interest. Further, its properties, both chemical and physical, are dependent on the molecular weight distribution in the product; this in turn is affected very markedly by the conditions of synthesis, which can be varied widely. It has been found that the most satisfactory method of classification of different polythenes is by the measurement of the liquid viscosity of the molten polymer at 190° C in a viscometer of special design. This method has the technical advantage of giving a measure of the extrudability of the product in extrusion machinery.

The solubility of the present commercial product in most organic solvents is very low at ordinary temperatures. It increases fairly rapidly between 50–70° C, although very high molecular weight products are not readily soluble in any solvent even above the melting-point, and show very rubbery characteristics at temperatures over 100° C. Polythene is unaffected at room temperature by such reagents as hydrochloric and nitric acids or 50 per cent. caustic soda, but it is attacked strongly by chlorosulphonic acid. At higher temperatures, in the neighbourhood of 100° C, it is still unaffected by hydrochloric acid and 50 per cent. caustic soda, but is attacked by nitric and sulphuric acids. Because of its saturated nature it is affected by ozone to a very much smaller extent than rubber, and this—as in the case of many other plastics—is an important property in electrical applications.

Polythene can be chlorinated in solution or suspension to give products with varying amounts of chlorine in the chain, and a series of plastic products—the mechanical properties of which depend on the chlorine content—can be produced, ranging from rubbery to hard solids. Polythene when hot oxidizes in air, but, as would be expected from its constitution, to a very much smaller extent than rubber. Recently it has been found that the introduction of suitable anti-oxidants inhibits the oxidation almost entirely, in the temperature range required for fabrication. This fact is of importance in the technical applications of the product, since oxidation is accompanied by a rise in power factor owing to the introduction of polar groups into the chains. When oxygen is excluded and polythene is heated in a high vacuum, it remains unchanged up to temperatures of 300° C. Above this temperature chain breakdown occurs, and brittle waxes, greases, and oils are formed.

Whilst, then, the product behaves chemically in a manner to be expected from its structure, its physical properties are unique for a saturated hydrocarbon; it is tough and flexible and possesses very great impact strength.

Polythene is a crystalline plastic, and its mechanical behaviour closely resembles that of the other polymers in this class, such as nylon, the vinylidene chloride polymers, and the natural products gutta-percha and balata. On applying tension to a test specimen it elongates in a regular manner over the whole length until the stress has reached a critical value, normally about 100 kgm. per square centimetre, and at this point the specimen separates into two regions, the drawn and the undrawn, separated by definite shoulders, as can be seen clearly in figure 4. This remarkable behaviour is of very great interest, both scientifically and technically. The ratio of the cross-sections of the two regions depends to a certain extent on the nature of the polythene and on the conditions of the drawing process, but is generally about 4 or 5 to 1. As the cold drawing process takes place, elongation proceeds at nearly constant stress until the specimen is cold drawn over the whole length and has increased four- or fivefold in length.

As in the case of other polymers of this kind, the orientation is clearly shown by examination under the polarizing microscope or by X-rays, which reveal a characteristic fibre diagram (*see* figure 2). It is now possible, in the case of crystalline polymers, to picture the change which takes place in the drawing process. Undrawn polythene consists of spherulitic aggregates of ordered regions or crystallites which can be seen under the

polarizing microscope. The crystallites are to be regarded as ordered regions from which the chains project and are continued into non-oriented amorphous regions and into other crystallites. The sizes of the spherulites can be varied by thermal treatment; thus, by shock cooling, thin films can be made which are more transparent and flexible than ones which have been slowly cooled, and such films will cold draw more easily and at a lower stress. During the initial stages of stretching, orientation of the crystals takes place and can be detected by measurement of birefringence or by X-ray photography. On cold drawing, the crystallites are pulled into approximately parallel orientation, the long molecules becoming parallel to the direction of drawing; and during the process the crystals may be to some extent broken down to smaller ones. There may also be some reunion—in other words, recrystallization may occur.

On heating at temperatures below the melting-point, this state of order tends to disappear, and the specimen will retract. The orientation can, however, be completely removed only by heating above the melting-point, although in the case of polythene of very high molecular weight, and therefore of very high liquid viscosity, extrusion or stretching produces some orientation of the molecules even above this temperature. It is of interest to compare this phenomenon with the stretching of rubber, where the rubber molecules themselves are oriented by stretching until crystallization takes place. This disappears on releasing the stress, because the freedom of rotation in unsaturated substituted chains is greater than in the saturated polythene chains at room temperature. However, rubber at low temperatures will crystallize and will also show the phenomenon of cold drawing.

The X-ray diffraction pattern of polythene shows the presence of amorphous as well as crystalline regions; and the relative amounts of the two are of great interest, not only in the case of polythene but in the case of other crystalline polymers, since it has been found that slight changes can profoundly affect some of the more important mechanical properties. Examinations of the changes in physical properties (such as density and specific heat) with temperature indicate that there is a regular but increasingly rapid decline in the crystallinity of polythene as the temperature rises, the final traces of crystalline material disappearing at the melting-point.

Whilst polythene for many purposes requires no plasticizer, a means of controlling the softness in technical applications is of value. The most satisfactory plasticizer has been found to be polyisobutylene of high molecular weight, which being rubbery gives the polymer a useful plastic range; it does not affect the dielectric constant or power factor, since it itself possesses a hydrocarbon structure. Amounts as small as 10 per cent. increase the flexibility of polythene at low temperatures; but changing the molecular weight distribution by altering the conditions of the synthesis produces the same effect without any plasticizer.

The large variations that can be obtained in low-temperature flexibility of polythene, which in the early stages of manufacture were little understood, made it necessary to examine in greater detail the effect of the molecular weight distribution on the mechanical properties. Measurement of distribution by such methods as fractionation and the ultra-centrifuge is tedious and difficult, and it has been found that other properties such as the solubility and the viscosity of the polymer in the molten state can be used to determine changes in distribution qualitatively. As a result of these studies it may be said that the tensile strength, the impact strength, and the flexibility at low temperatures are improved by an increase in average molecular weight, whilst for a given average there may be an optimum distribution of molecular weight. The deleterious effect on the mechanical properties (particularly the low-temperature flexibility) of an unduly large proportion of low molecular weight material has now been abundantly demonstrated. High molecular weight polythenes of higher tensile strength have been produced which are also flexible at −100° C, but these materials are somewhat more difficult to process with the machinery used for handling the normal commercial product. This is in striking contrast to amorphous polymers which, when heavily plasticized to give increased low-temperature flexibility, become weaker at ordinary temperatures.

In the case of the electrical applications in which polythene has been used already, and may be used more in the future, the combination of the electrical and mechanical properties is all-important. The low power factor of 0·0002–0·0003, whilst not being independent of frequency, shows only a sluggish variation over the widest range examined; and because the water absorption and permeability are so very small, it is practically independent of humidity, a fact of very great practical importance. These properties

have already established polythene in telecommunication cables. The high breakdown voltage of polythene, combined with its other electrical properties, makes it attractive also as a possible insulant for high-voltage cables, provided that the difficulties due to the large thermal expansion can be overcome, and that the extrusion of the plastic can be carried out in practice with complete absence of voids. In extruding polythene or mixtures of polythene and polyisobutylene over wire, normal rubber screw forcing machines, preferably of the roller feed type, are used. The barrel temperature must be above the melting-point of 115° C and the temperature of the die should be between 130–160° C, depending on the liquid viscosity of the polythene used. If the die temperature is too high, excessive cooling of the extruded sections will be required, which will tend to cause voids in the extruded section. Where it is desired to protect the cable with an abrasion-resistant sheath, plasticized polyvinyl chloride compositions rather than rubber should be used, since sulphur diffuses into polythene.

The properties of polythene make it a very desirable material, in common with other plastics, for many purposes in which chemical resistance is of importance. The fact that above its melting-point it is a liquid which can be pumped at comparatively low pressure by normal extrusion machinery makes the production of large flawless mouldings possible by the technique of extrusion moulding. In this technique the plastic is injected by means of an extrusion machine into a mould constructed to stand about 200 lb. per square inch, provided with an injection hole which is clamped against the nozzle of the extruder. For large mouldings it may be necessary to heat the mould to 90–100° C. Small blowholes for the escape of air are provided at points removed from the extrusion nozzle, and when the polythene comes through them the mould is shown to be full. Cooling is started at the point furthest from the injection nozzle, the pressure being maintained until the mould is full. Tubing can be made by extrusion or, in the case of larger diameters, by welding sheet which has been produced by slicing blocks in a cutting machine. Powder of suitably small particle size can be successfully sprayed, by means of a gun similar to that used for spraying metals, to give coherent films on metal surfaces, and this offers the most convenient method of coating objects of irregular shape.

Films of very low water permeability can be produced from solution or by extrusion, although the latter method is to be preferred except where very thin film is required, and the mechanical properties can be varied by the conditions of manufacture. Thus, if extrusion is followed by rolling, orientation occurs in the direction of rolling, and the strength is greater in the longitudinal than in the transverse direction. The conditions of cooling affect the transparency of the film to a marked degree, shock cooling producing small spherulites and greater transparency. Fibres can also be produced, and the most interesting variations in orientation can be obtained, leading to different mechanical properties, and these are being further studied at the present time. In the development of technique for the fabrication of polythene, the crystalline nature of the material must be kept constantly in mind. Many uses have been found for the material, and many more will undoubtedly appear when opportunity occurs again for developing them after the war.

Quite apart, however, from the present and future technical applications, work on polythene is adding greatly to our knowledge of hydrocarbons and high polymers generally. It is the simple structure of the methylene chain that makes it such an attractive starting material for the systematic study of mechanical, chemical, and electrical properties of high polymers. Such work is more difficult, and almost impossible, when more complicated molecular systems are chosen.

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# The chemical destruction of forest pests

LEON L. OSSOWSKI

In virgin woodlands and forests there is a natural equilibrium between plant and animal (including insect) life. When man interferes, for example by the regimented planting of conifers, the balance is likely to be disturbed, and insect pests may flourish under the new conditions. The Head of the Forestry Department in the Polish Ministry of Reconstruction here describes some of these pests and the chemical counter-measures taken against them.

The steady increase in the number of insects harmful to woodlands, such as the nun moth (*Liparis monacha* L.), the pine looper (*Bupalus piniaria* L.), the pine noctuid (*Noctua piniperda* Panz.), and the pine moth (*Dendrolinus pini* L.), among the order Macrolepidoptera (large butterflies and moths), and, among the order Hymenoptera, the pine sawfly (*Lophyrus pini* L.), presents a serious forestry problem. It is chiefly conifers that are threatened and rarely deciduous trees. Various more or less successful means of combating these insects are at the disposal of foresters.

Before giving a description of the present scientific position as regards control measures, something should be said about the magnitude and causes of the outbreaks of insect plagues in the last fifty years, the extent of effective control, and the development of the most important methods hitherto elaborated.

Without definite figures it is impossible to realize the enormous damage done by these insect pests. In 1890, 12,000 acres of spruce in Bavaria [2] were completely destroyed by the nun moth. In 1918–23 the same insect attacked in Czechoslovakia about 600,000 acres of spruce (and pine), of which 70,000 acres were entirely ruined. In Bavaria [1] in 1895 the pine looper attacked about 100,000 acres of coniferous woods, in consequence of which 5,000,000 cu. ft. of timber had to be felled. In the past two decades the pine looper, the pine moth, and pine noctuid severely ravaged woods in Central and Eastern Europe, laying waste in the years 1921–25 about 200,000 acres of softwoods in the provinces of Brandenburg and Mecklenburg, and 250,000 acres in Poland.

Again in the years 1931–33 the cost of fighting the pine noctuid in one province of Poland alone amounted to £140,000. The foregoing figures represent only a small part of the havoc wrought by moths. It is during the past century that insect plagues have become more serious. This is undoubtedly because man by his activities has upset the natural balance of woodland life. The replacement of natural forests, with trees of different kinds and different ages; by conifers, generally of one species and of uniform age, has given the caterpillars of pine moth, noctuid, and looper, the larva and adult insect of all pine shoot beetles (*Myelophilus*), and other destructive insects, abundant supplies of suitable food. Nature has protested, by infliction of heavy disasters, against unnatural innovation upon the original and natural form of the primitive forest. The modern forest has no chance of self-regulation, and even a slight disturbance may suffice to upset its equilibrium.

The course of such an insect plague takes a characteristic form, in respect of the period and manner of the outbreak and its decline, which reminds one of the temperature curve in human diseases. Five stages in the development of a forest insect pest can be distinguished: (i) the initial stage, in which the first stimulus is given to an increase in insect population; (ii) the prodromal stage, in which the harmful symptoms are noticeable, though not dangerous; (iii) the eruptive stage, which is the most dangerous and causes a complete defoliation; (iv) the crisis, which leads to (v) the stage of abatement, during which the mass-increase generally disappears and the insect population returns to normal. A picture of the course of the disaster can be given by curves, reflecting the rapidity of its development.

Figure 1 shows observations of the various stages of the development of the pine looper, made during 1925–36 in a 0·5 hectare sample plot of a

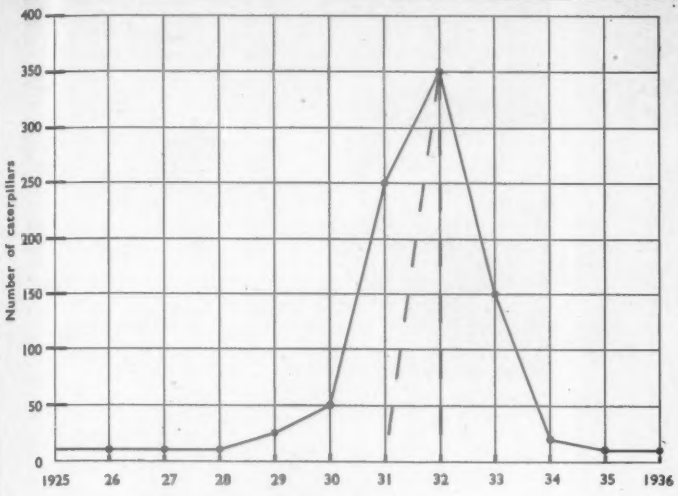



FIGURE 1

1925–28, 34–36: *normal years.*
1928–30: *two years of initial stage.*
1930–31: *prodromal stage.*
1931–32: *eruptive stage and crisis.*
1932–34: *stage of abatement.*

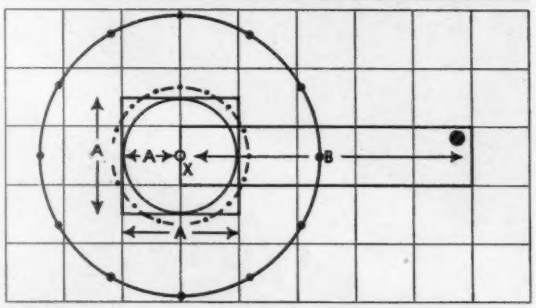
45-year old European pine (*Pinus sylvestris*) plantation.

The magnitude of an insect plague is determined by climatic and other factors, especially the presence of insect parasites. Every noxious insect has a group of parasites, principally *Ichneumonidae*, *Braconidae*, and *Tachinidae*, which chiefly infect the grubs and caterpillars. One may note some parasites found on the pine noctuid, the pine looper, and sawflies. On the first of these live [15] *Ernestia rudis* Fall., *Ichneumon pachymerus* Htg., *Trichogramma evanescens* Wetw.; on the second, *Cordiceps militaris*, *Ichneumon nigritarius* Grav., *and I. binunulatus* Grav.; on the third, *Externus cingulatorius* Holmgr., *Spilocryptus nubeculatus* Grav., *Externus oriolus* Hart., and many others. The importance of the parasites is slightly diminished by the presence of hyperparasites upon them, e.g. on *Tachina larvarum* the hyperparasite *Phygadeuon Schimitscheki* Fahringer [9, 10]. Microfungi, as *Isaria* sp. and *Fusarium* sp., also exercise no small influence on the course of a plague.

Science has made progress in detecting signs of an approaching outbreak, based on a more exact knowledge of the life-habits of various insects. Whereas the caterpillars of the pine moth creep down the tree trunk in autumn in order to spend the winter (as caterpillars) close to the bole under the surface of the ground, the caterpillars of the noctuid and looper crawl a considerable distance away from the trunk before they settle down under the surface of the ground. Here the change to the pupal stage takes place and the winter rest follows. Earlier tests over a quadrat of 1 m. sides, or a circular area of the same diameter around the trunk, have given a true picture of the presence of the pine moth only. To arrive at a just conception of the population of looper and noctuid a rectangular space of 5 m. by 1 m. has to be marked off, enclosing two trees, one near each end. Figure 2 shows the comparison between the earlier and the more recent tests and the suitability of the latter with regard to the looper and the noctuid.

Again, with the nun moth it is advisable to refrain from the obsolete method of counting the clusters and eggs, for this test does not give accurate results; the eggs are so minute as to escape notice in the majority of cases. It is more satisfactory to examine the chrysalis and ascertain its sex and the extent of its reproductive power.

Before chemical methods were introduced on a considerable scale, attempts were made to fight the outbreak of an insect plague by raking the surface of plantations after the time at which the caterpillars became pupae (in the case of looper and noctuid); by collecting the moths (in the case of the nun moth); and by placing a ring of tar round the trees attacked by the pine moth. All these methods have been used on a grand scale and




*Sample plots.* FIGURE 2

*A. Old methods for pine looper, pine noctuid and pine moth* (Dendrolinus).
*B. New method for pine looper and pine noctuid.*
● *Tree.*
*Approximate area occupied around tree "X" during hibernation of pine looper, pine noctuid.*
*Approximate area occupied around tree "X" during hibernation of pine moth.*

FIGURE 3 – *Pine forest destroyed by pine looper.*

FIGURE 4 – *Nun moth on tree trunk.*
(*From Hoffmann, C. H.*, Nachr. SchädlBekämpf., Leverkusen.)

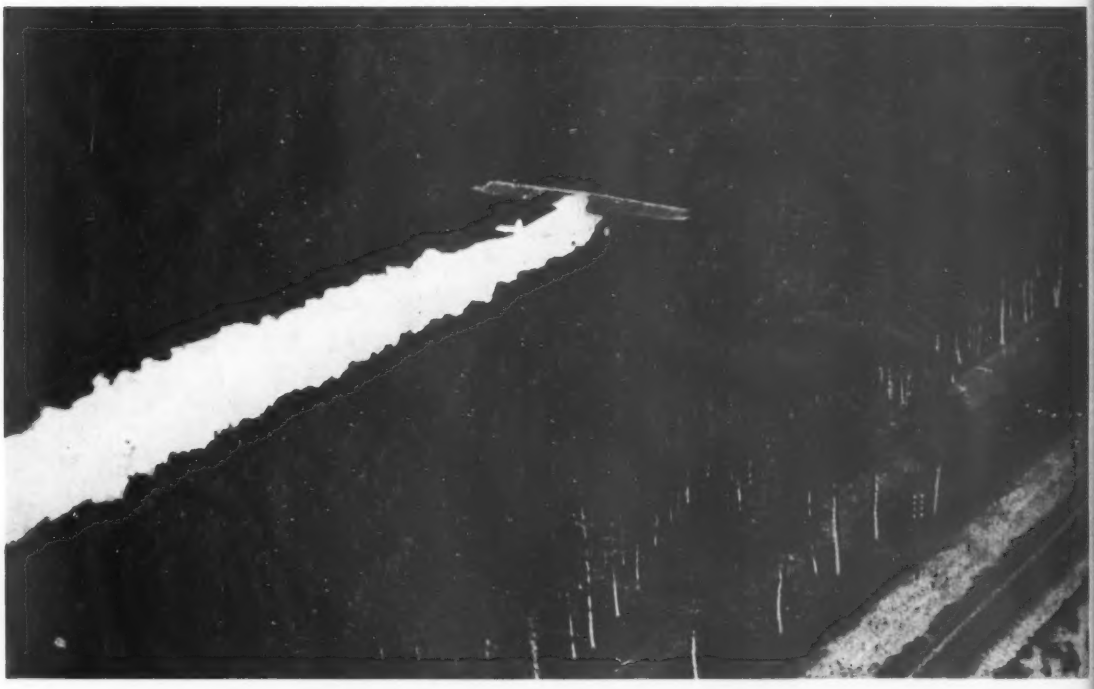
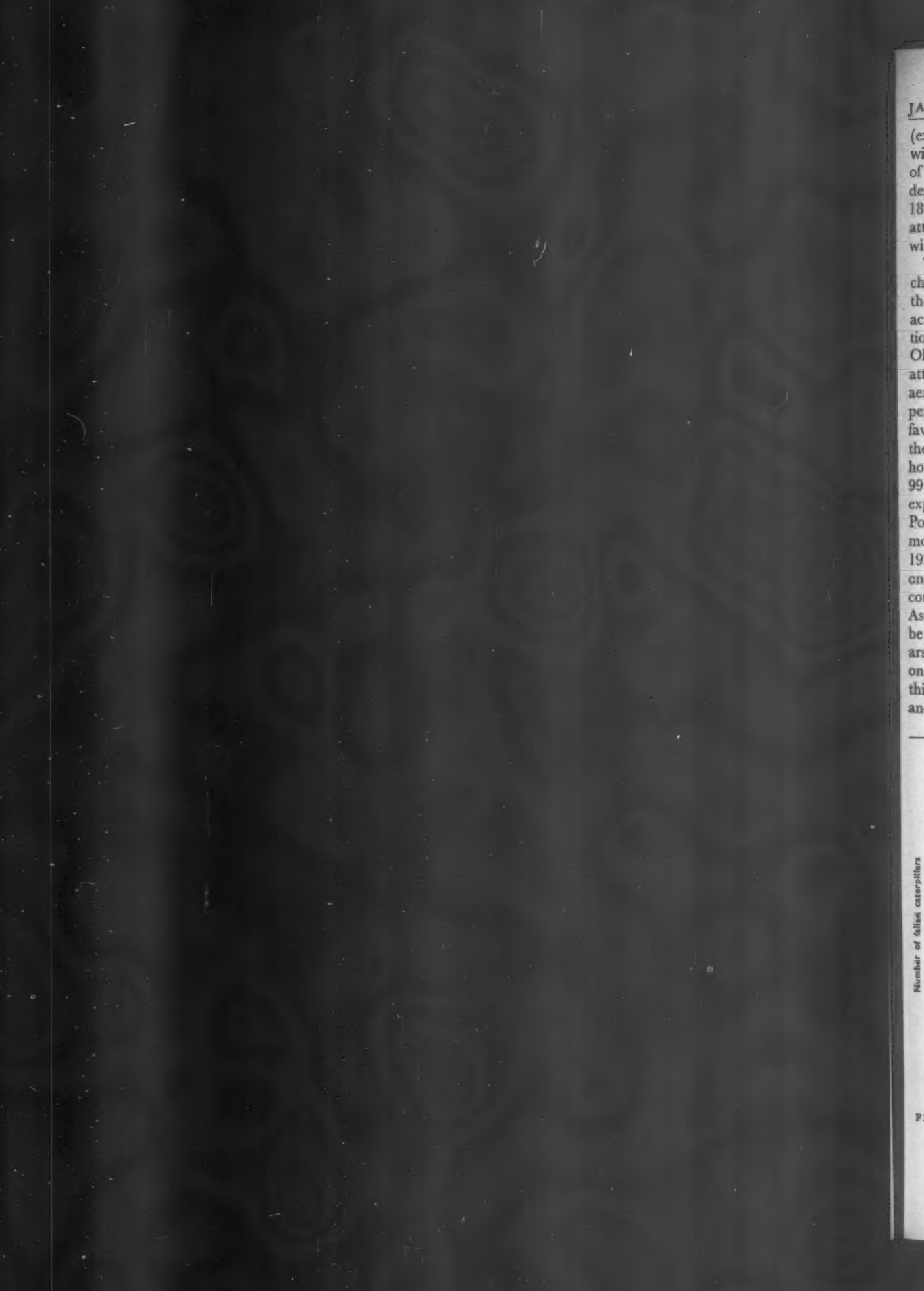


FIGURE 5 – *Aeroplane diffusing poison over a forest attacked by defoliating caterpillars.*



(except in the use of tar against the pine moth) with only moderate success. Experts then thought of trying the effect of chemical methods against destructive insects. The first trial was made in 1890 in Bavaria, against the nun moth. The attempt failed, as technical facilities for dusting with powder were lacking.

The first extensive experiment on the use of chemicals to destroy insects was made in 1921 in the U.S.A. by C. R. Neillie and J. S. Houser, acting with the co-operation of the Federal Aviation Experiment Station at McCook Field, Dayton, Ohio [14]. A field of *Catalpa speciosa*, which was attacked by *Ceratomia catalpa*, was dusted from an aeroplane with arsenates of lead ($As_2O_3$ = 45·06 per cent., PbO = 54·84 per cent.). Thanks to favourable (warm and dry) weather conditions, the test met with complete success. After 48 hours the effect of the poison could be ascertained: 99 per cent. of the caterpillars were dead. This experiment was followed by others in Germany, Poland, and Czechoslovakia against the nun moth, pine looper, and pine noctuid. Up to 1928–29 tests were carried out on a large scale on the Continent, using arsenates of calcium containing up to 70 per cent. of arsenious oxide, $As_2O_3$. The results, however, left much to be desired, owing to the fact that the efficacy of arsenic, which acts as an internal poison, depends on weather conditions. A further disadvantage of this chemical is the danger of poisoning mammals and birds. 10–12 grams of $As_2O_3$ will kill a cow, 0·5 gram a pig. Experts in both chemistry and forestry had therefore to try to find a poison fatal to insects but free from these drawbacks.

The first large-scale outdoor experiments with so-called contact dust were made in 1929–30. The effect of these powders is independent of the feeding activities of the caterpillars. To kill them it is only necessary to sprinkle powder on their skin. It causes paralysis and later destruction of the nervous and muscular systems. A great advantage of the use of external poison lies in its independence of weather conditions. Internal poisons are effective only when the caterpillars are actively feeding, and this depends on the weather.

It has been proved that the caterpillars of the pine looper and noctuid abstain for as long as three days from eating the needles sprayed with arsenic. If rain falls during this period the needles are washed clean and the process of dusting has to be repeated. The contact dusts are free from these defects. The first contact dusts were based on veratrin or rotenon, or were derived from the roots of *Derris robusta* (from India). They also contained some sulphate and nicotine. These powders were manufactured at various chemical factories and given different names, e.g. 'forestit' and 'verindal' (Germany), 'choinit' (Poland), and 'polvo' (England) [5]. All these products were used successfully.

In 1931–32 an area of about 150,000 acres attacked by the pine looper in Brandenburg was

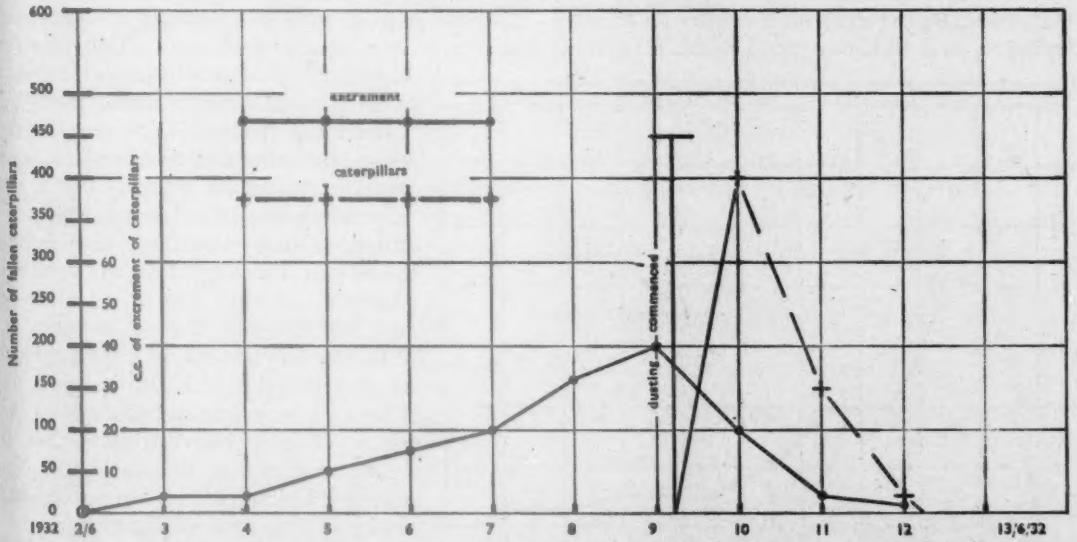



FIGURE 6 – *Showing the fallen excrement and dead caterpillars before and after commencement of dusting with 'choinit.'*

treated with 'forestit'. Again in 1932 'forestit' and 'choinit' were used in Poland against the pine noctuid, and about 170,000 acres of coniferous plantations were dusted with great success.

Some details of the operation in Poland are of interest. The amount of 'forestit' or 'choinit' used was 50 kgm. per hectare. It was usually applied in the early morning and late afternoon, and only in calm weather was the application continued the whole day. The caterpillars were then between the first and third moults. The attacked stands were dusted only once. To test the effect of the operation, sheets of linen about 2 m. square were laid in various places and the volume of the excreta falling on them before and after dusting was measured; the number of dead caterpillars was also found after the operation. Figures 6 and 7 show the effect of the contact dusts.

In Russia [13] the dusting is started as soon as possible after all the eggs are hatched. The smaller the larvae are, the smaller is the amount of dust required to kill them.

It may be stated that in the Polish woods treated with 'choinit' there were ten healthy pupae in 1 sq. m. of ground, and the number of eggs on a tree-trunk was 1,800–2,200. On the area treated with 'forestit' the corresponding numbers were thirteen pupae and 2,100–2,500 eggs.

About 1 minute after the cloud of poison had touched the tops of the trees, half-dead caterpillars began to fall, and this continued for hours. Neither 'forestit' nor 'choinit' was harmful to mammals or birds. They affected only very slightly the mucous membrane of the human body. As a final result, 98 per cent. of the caterpillars were destroyed, and all the areas of Polish woodlands attacked by the pine noctuid in 1931–33 were saved. Contact dusts, based on veratrin, derris, and rotenon, were found to be effective only against hairless caterpillars. They proved less successful against hairy caterpillars such as those of the nun and pine moth, which 'forestit' also completely failed to kill.

A great advance was made in 1932 by the addition of pyrethrum to the contents of the dusts, making them effective against hairy caterpillars. This preparation is produced from the blossoms of certain species of chrysanthemum (*C. marschallii* Aschers, *C. roseum* Adam, and particularly *C. cinerariaefolium* Vis.). The percentage of pyrethrum in the chrysanthemum depends upon the type of the soil and the development of the plant. For a long time there was uncertainty as to the effective elements of preparations of pyrethrum. Rother found three acids which he called persicin, persiretrin, and persitrin. Belesme (1876) found an alkaloid which he called chrysanthemin. Later researches by Staudinger and Ružicka [12] established the existence of two liquids, called by them pyrethrine I and II. They are the esters of the same alcohol, pyrethrolon (methylpentadienyl-cyclopentanolon). Pyrethrine is the pyrethrolon ester of chrysanthemum monocarboxylic acid, pyrethrine II the ester of chrysanthemum dicarboxylic acid. Both esters are poisons affecting the nervous and muscular systems of insects. The efficacy of pyrethrum depends on the age of the caterpillars, but it persists up to the time of the fourth moult. Pyrethrum has the defect that the pyrethrine in it decomposes very easily. This preparation is in general not harmful to man and animals. Occasionally, unpleasant effects may be experienced, but only by persons subject to the so-called 'pyrethrum idiosyncrasy.'

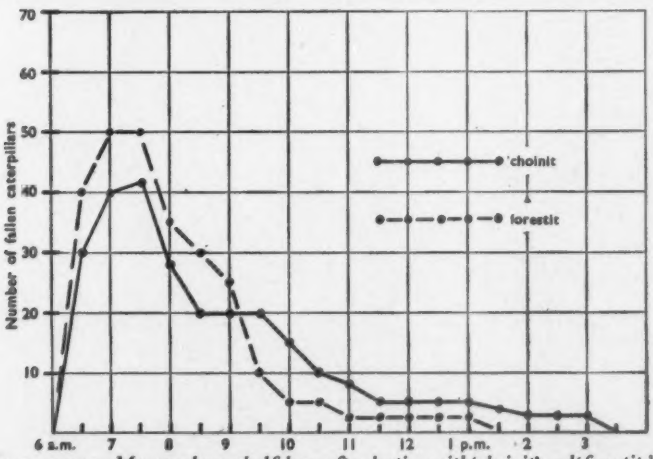



FIGURE 7 – *Measured every half-hour after dusting with 'choinit' and 'forestit.'*

Later experiments (1936) were made against the nun moth with contact dusts based on dinitro-*o*-cresol [11]. All hairy caterpillars, even the largest, were destroyed. This preparation, however, has the serious drawback that it is a potent poison if absorbed into the bodies of men and animals. Persons engaged in sprinkling it must wear masks and special clothing and gloves. It also causes signs of burning on young shoots of spruce [4] and on all broad-leaved trees, so that, if a plantation of these is attacked by destructive insects, dinitro-*o*-cresol should not be used to exterminate them.

In recent years, before the outbreak of

the war, small experiments were made with preparations produced by a German chemical firm. Their success was said to be complete [4]. Even the strongest of the nun moth caterpillars were killed and the powder had no injurious effect on men or on warm-blooded animals [4]. The outbreak of the war stopped further experiments.

Motor dusters and aeroplanes [3, 6] were and are used for the distribution of arsenic and contact dusts. Trials were also made with autogyros [7, 8] and balloons. All methods have their advantages and disadvantages. Aeroplanes can be used only if large areas are to be treated. Further, the velocity of the planes is too great to ensure a uniform distribution of the powder. Aeroplanes, too, depend on aerodromes and other equipment. The autogyro is a more convenient type of plane, as it is not so fast and the distribution of the poison can thus be more evenly regulated. It requires, too, only a small space for taking off and landing. Motor dusters can be used in smaller areas. They have the advantage that they sprinkle the trees twice, once when the cloud of dust is rising and the second time when it settles. A great drawback is their extreme dependence on wind conditions. The morning hours are the most favourable for dusting operations, as the wind is usually not so high then as in the middle of the day; also the turbulency of the air is at its lowest at sunrise. Only in very calm weather can the process of dusting be carried on all day long.

FIGURE 8 – *Trunk of European pine, showing the deadly effect of contact dusts to caterpillars of the pine noctuid.*

Today, therefore, we possess well-recognized means of fighting insect plagues in the form of contact dusts, but so far they are effective only against hairless caterpillars. They are fatal to the caterpillar and harmless to human beings and animals. Pyrethrum and dinitro-*o*-cresol preparations are also effective against insects, but are only a temporary solution of the problem of the destruction of the hairy caterpillar.

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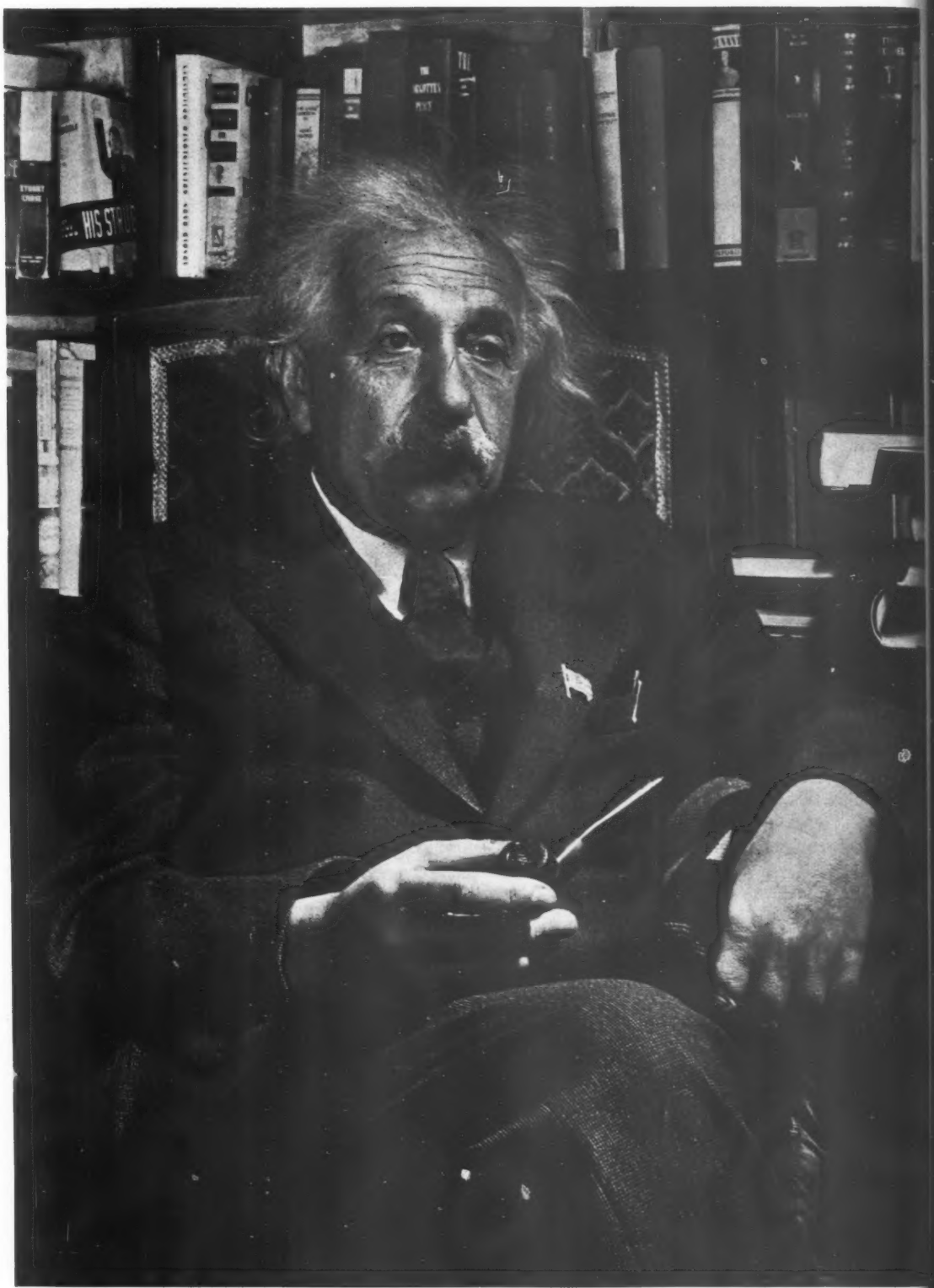


ALBERT EINSTEIN

# Old and new ideas of gravitation

E. T. WHITTAKER

In a previous article, Professor Whittaker described the origin, development, and final abandonment of the conception of an aether. The present article, though complete in itself, may be regarded as a sequel to the former one: it tells the story of man's attempts to construct a unitary theory of the external world by discovering relations between gravity, electricity, magnetism, and light. The science of cosmology may help to solve the mystery.

Although gravity was the first of the forces of Nature to be brought within the domain of exact science and represented by a mathematical formula, and although a prodigious amount of highly successful work has been done in the development of the theory, yet the fundamental physical problems connected with it are almost as perplexing today as they have ever been. The Law of Newton, that every particle in the universe attracts every other particle with a force inversely proportional to the square of the distance, provides a method of calculating the effects of gravitational action; and in the course of the eighteenth and nineteenth centuries all the known motions of the heavenly bodies (with one small discrepancy, which was ultimately accounted for by Einstein) were explained satisfactorily by its means. But the Newtonian theory undertook no more than to predict observable behaviour, to answer the question How? It made no attempt to ask What? or Why? or to determine the origin or mode of transmission of the influence, or its connection with the other natural forces.

These wider problems, however, have never been absent from the minds of physicists, and from time to time during the last two centuries efforts have been made to understand the conveyance of gravitational force, to determine whether it is propagated instantaneously or in time, and to discover relations between gravitation, electricity, magnetism, and light, with a view to constructing a *unitary theory* of the external world. From the time of Newton to the discovery of the general theory of relativity in 1915, these investigations were of three main types: first, those which attempted to provide a rationale of the process of transmission by postulating hidden mechanisms and hypothetical aethers; secondly, those which subjected the hypothesis of instantaneous propagation to a critical examination, comparing astronomical observations with the calculated results of various laws involving propagation in time; and, thirdly, purely experimental researches undertaken in the hope of obtaining electrical effects as a consequence of gravitational actions. After the discovery of general relativity, the character of the problem was radically changed and a new line of approach was indicated; the very considerable activity of the last twenty-five years has been inspired for the most part either by new developments in geometry or else by quantum theory. In the present article it is proposed to give some account of the most illuminating contributions to the solution of the mystery.

Of the earlier attempts, we may single out those which tried to find where gravitational energy is located. If two particles, originally at rest at a distance from each other, are free to move under the influence of their mutual attraction, they acquire velocities; that is to say, kinetic energy makes its appearance. This energy must (so the Victorian physicists argued) have been somewhere, in some form, before the motion began: where was it? That this was not a meaningless or hopeless question seemed to be indicated by the fact that the corresponding problem with regard to electricity and magnetism had already been solved. The energy of a system of magnets, corresponding to the forces they exert on each other, was originally found as a mathematical expression in terms of the positions of the magnets. In 1853, however, William Thomson (Lord Kelvin) showed that this expression could be transformed into an integral taken over infinite space; whereupon, by a stroke of genius, he proposed the physical doctrine that the energy was not localized in the magnets, but was distributed over the whole magnetic field. This principle, and a similar one with regard to electric charges, were adopted by Maxwell, and on them was founded the electromagnetic theory of light.

Could something similar be done for gravitation? Gravitational forces obey the same law (the inverse square of the distance) as electric and magnetic forces, and the lines of gravitational force near two dense bodies are exactly of the same form as the lines of magnetic force near two like poles. The only difference is that, whereas the poles are repelled, the bodies are attracted. Mathematically, there is a change from a plus to a minus sign, which does not affect the possibility of working out the gravitational analogue of Thomson's magnetic theorem, and it was obtained without any difficulty in 1865 by Maxwell; but the minus sign played havoc with the possibility of a physical interpretation, for the energy density was found to be smaller at places where the gravitational force was intense than at places where it was feeble. Now (argued Maxwell) as energy is essentially positive, it is impossible for any part of space to have negative intrinsic energy. Hence the assumption that gravitation arises from the action of the surrounding medium leads to the conclusion that every part of this medium possesses, when undisturbed, an enormous positive intrinsic energy, and that the presence of dense bodies influences the medium so as to diminish this energy wherever there is a resultant attraction. 'As I am unable to understand in what way a medium can possess such properties,' he concluded, 'I cannot go further in this direction in searching for the cause of gravitation.'

The curious sequel of this story is that the concept of negative energy has been introduced and is actually accepted in modern quantum mechanics. An electron in a field of force can make transitions to states in which the energy is negative, and these states play, formally at any rate, an important part in the theory of scattering. Maxwell's difficulty might therefore not seem so serious to us as it did to him; but, as we shall see later, his proposal is now in disfavour for other reasons.

Another question which attracted attention in the nineteenth century was that of the propagation of gravitation: was it instantaneous, or did it occupy a finite time? The only way to settle the matter was to work out mathematically the consequences of various hypotheses and compare them with the results of astronomical observation. (The function of observation is not to furnish hypotheses, but to test them.) One hypothesis was that the force obeyed Newton's Law as to its magnitude, but did not act until it had been transmitted with a definite velocity across the space separating the planet from the sun. This had to be rejected, since it was found that the velocity would have to be at least a million times that of light. The next suggestions were borrowed from electrodynamics. It had been shown in the middle of the century that the ponderomotive forces between electric currents, and the induction of currents, could be explained by assuming the law of force between two electrified particles to consist not only of the ordinary electrostatic term (repulsion according to the inverse square of the distance), but also of a term depending on their velocities[1]. It seemed natural to suggest that the law of gravitation might be of some such character, Newton's Law being merely an approximation valid for the case when the velocity of the bodies is negligible compared with the velocity of propagation of gravitational force. Attempts were made to use this idea in order to account for the secular motion of the perihelion of the planet Mercury, which could not be explained by the simple Newtonian Law; but the results obtained depended so much on *ad hoc* assumptions that they were not felt to be convincing.

Another of the older lines of investigation was experimental in character, and is best represented by the researches described in Faraday's Bakerian Lecture of 1850, *On the Possible Relation of Gravity to Electricity*. The idea inspiring the work was that as two bodies moved towards each other by the force of gravity, electric currents might be developed either in them or in the surrounding matter. Several experiments were performed to test this speculation, but the results were negative. 'They do not,' said Faraday in conclusion, 'shake my strong feeling of the existence of a relation between gravity and electricity, though they give no proof that such a relation exists.'

The age of natural philosophy which began with Newton may be regarded as closing with the death in 1907 of Lord Kelvin, who to the end never relaxed his efforts to solve the great question, Is action at a distance a reality, or is gravitation to be explained, as it was now believed magnetic and electric forces could be, by the action of intervening matter? At one time he had great hopes of an approach by way of hydrodynamics; cyclic irrotational motion, once established through an aperture in a movable solid immersed in a

[1]This (now discarded) was a true 'electron theory,' since it involved only forces between particles, without bringing in a medium, as the later and better-known electron theory of Lorentz did.

liquid, continues for ever after with circulation unchanged, however the solid moves; and if there be any other solid at a distance from the first, there will be mutual forces between them. The attempt to bring this property into exact correspondence with gravitational phenomena, by regarding the circulation as the analogue of mass, proved, however, to be impracticable; the true method of replacing action at a distance by contiguous action was yet to come.

It was adumbrated in the last decade of the nineteenth century by Kelvin's friend FitzGerald, in the words: 'Gravity is probably due to a change of structure of the aether, produced by the presence of matter'; but the credit for the successful development of this idea is due wholly to Einstein, who published his theory of general relativity in 1915. The 'aether' of FitzGerald was called by Einstein simply 'space' or 'space-time': and FitzGerald's somewhat vague term 'structure' became with Einstein the more definite and precise 'curvature.' Thus we obtain the central proposition of the Einsteinian theory: 'Gravity is due to a change in the curvature of space-time, produced by the presence of matter.'

What differentiates this from all previous conceptions is that the older physicists had regarded gravity as merely one among many types of natural force—electric, magnetic, etc.—each of which influenced in its own way the motion of material particles. Space, whose properties were set forth in Euclidean geometry, was, so to speak, the stage on which the forces played their parts. But in the new theory, gravity was no longer one of the players but part of the structure of the stage. A gravitational field consisted essentially in a replacement of the Euclidean properties by a much more complicated kind of geometry: space was no longer homogeneous or isotropic. An analogy may be drawn from the game of bowls. Bowling-greens, in the North of England, are not flat, but rise to a slight elevation in the centre. An observer who failed to notice the central elevation would find that a bowl (supposed without bias) always described a path convex towards the centre of the green, and might account for this by postulating a centre of repellent force there. A better-informed observer would attribute the phenomenon to a geometrical feature—the slope. The two explanations correspond respectively to the Newtonian and Einsteinian conceptions of gravity: for Newton it is a force, for Einstein it is a modification of the geometry of space.

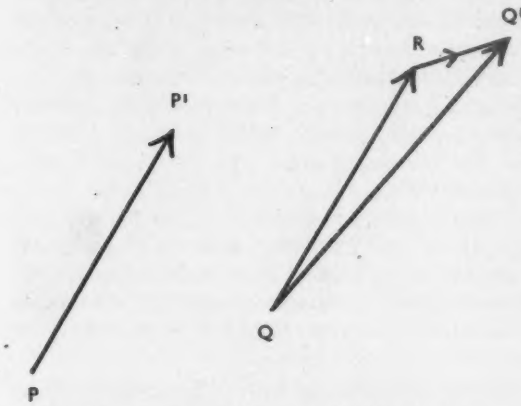
The new theory transformed completely the relation between gravity and the other natural forces. Instead of being isolated and unrelated to them, it was now the framework within which they acted, and therefore a potent influence on them all. For example, a ray of light in its passage from a star to the earth would be appreciably deflected if it passed very near the strong gravitational field of the sun; and an electrified body, or a single electron, which is at rest in a varying gravitational field, must emit radiation. Indeed, now that a definite connexion had been set up between electricity and gravitation, the whole of electromagnetic theory needed to be rewritten.

There was, however, one unsatisfactory feature about all this—unsatisfactory, that is to say, from the aesthetic point of view only, for it was not in contradiction with any result of experiment. One of the natural forces, gravity, had been absorbed into geometry; but the others were still forces in the old Newtonian sense. Would the picture of the universe not be more satisfying if they could *all* be absorbed into geometry? Did not Faraday himself, in his theory of lines of electric and magnetic force, initiate some such development? In most of the work done since 1917, the dominant motive has been this idea of the complete geometrization of physics.

Evidently if the geometry in the neighbourhood of any point is to be capable of expressing the whole physical situation there—that is to say, the gravitational field and the electromagnetic field —then it must be a geometry much more elaborate than Euclidean geometry; it must, in fact, be the geometry of a generalized space possessing curvature. What the geometry of a simple type of curved space is like can be understood at once if we think of geometry on the surface of a sphere. On a sphere we can have 'spherical triangles' whose sides are arcs of great circles, and the trigonometry of these triangles is a generalization of plane trigonometry. Now the physicist represents a force by a vector, and therefore if our geometry is to represent physical fields we must have a theory of vectors in generalized space, and of their variation from point to point of the space. In Euclidean geometry the matter is very simple. If U and V are two vectors at the same point P, we can find the vector which is their difference by using the triangle of vectors. But if U is a vector at a point P and V is a vector at a different point Q, and if we want to find the vector which is the difference of U and V, it is

necessary (in principle) first to transfer U parallel to itself from the point P to the point Q, and then to find the difference of the two vectors at Q. Thus a process of transporting a direction parallel to itself, or *parallel transport*, is necessary for finding the difference of vectors at different points, and hence for the spatial differentiation of vectors: and this statement is true also in generalized space.

Let us, then, think of two points P and Q on the surface of the earth, regarded as a sphere; let U be a direction in the surface at P, and let V be a direction at Q. The directions U and V of course cannot (unless P happens to be the antipodes of Q) be parallel in the ordinary




*Let $PP^1$, $QQ^1$ represent vectors. To find their difference, we must transfer the vector $PP^1$ to the position $QR$ by parallel transport. The required difference is then $RQ^1$.*

Euclidean sense, i.e. parallel in the three-dimensional space in which the earth is immersed; but a new kind of parallelism can be defined, and that in many different ways. We might, for instance, say that V is derived by parallel transport from U if V and U have the same compass-bearing; so that, e.g., the north-east direction at one place on the earth's surface would be said to be parallel to the north-east direction at any other place.

There are now two different kinds of curve on the earth's surface which may be regarded as analogous to the straight line in the Euclidean plane. If we define a straight line by the property that it is the shortest distance between two points, then its analogue on the earth is a great circle, since this gives the shortest distance between two points on the spherical surface. But if we define a straight line by the property that it preserves the same direction along its whole length, or, more precisely, that its successive elements are derived from each other by parallel transport, then its analogue on the earth is the track of a ship whose compass-bearing is constant throughout her voyage; this is the curve called a *loxodrome*. The existence of the two families of curves, the great circles and the loxodromes, may be assimilated to the fact that if an electrostatic and a gravitational field coexist, the lines of electric force and the lines of gravitational force are two families of curves in space, and this rough analogy may serve to suggest how different physical phenomena may be represented simultaneously in terms of geometrical conceptions.

The geometry which is actually used in the modern theory may be said to regard space as formed of a great number of small pieces cemented together, so to speak, by a parallel transport; it is called *affine geometry*. In the latest memoir on the subject, which was published in the summer of 1943, Professor Schrödinger has shown that a very simple and natural assumption regarding the nature of the Lagrangian is sufficient to produce from straightforward affine geometry the complete system of the differential equations of the combined gravitational and electromagnetic fields. This is the closest approach yet made to realizing Faraday's dream of a unification of the forces of Nature.

That the mystery of gravitation will be completely and finally solved along these lines is, however, unlikely: for in recent years the rapidly developing science of cosmology has brought to light fresh aspects of it which seem to call for radically new treatment. Researches on the expanding universe, on the generation of the energy which is radiated by the stars, and on the dynamics of star-clusters, have all contributed to furnish tolerably concordant estimates of the age of the cosmos; and modern physical theory has to adapt itself to the conception of the Creation. In certain cosmological theories, notably that developed by Professor E. A. Milne since 1933 and that proposed by Professor Dirac in 1937, this is of dominating importance; both these distinguished investigators hold that the laws of nature may be expected to involve the *epoch*, i.e. the interval which has elapsed since the beginning of time: and in particular, that the constant of gravitation, as measured by us, has a value which belongs to the age we live in, but which it did not have a thousand million years ago. This suggests that the attack on the gravitational problem should be begun from the cosmological end: as is, in fact, the tendency of some recent researches.

# Book reviews

### TECHNIQUE OF SCANNING GENERATORS

Time Bases (Scanning Generators): their Design and Development, *by O. S. Puckle. Pp. xii + 204. Chapman & Hall Limited, London.* 1943. 16*s. net.*

This excellent monograph deals with all the more important electronic devices for producing the time-axis in cathode-ray oscillographs, television receivers, engine indicators, etc. It outlines the historical development, and provides an introduction to the fundamental principles of modern technique; with this knowledge a student should be well able not only to apply it to any particular purpose but also to understand easily all new developments and descriptions of inventions. The value of the work is much enhanced by a series of seven appendices (nearly one-third of the whole) describing the sealed-off low-voltage cathode-ray tube and the effects of time constants and other valve and circuit parameters. Numerous footnote references to papers, a useful bibliography, and an adequate index are provided. W.J.

### DICTIONARY OF ORGANIC COMPOUNDS

Dictionary of Organic Compounds, Volume I, *edited by I. M. Heilbron and H. M. Bunbury. Pp. xvi + 1072. Eyre & Spottiswoode Limited, London. New, revised, and enlarged edition,* 1943. £6 6*s. net.*

With Beilstein's *Handbuch* becoming increasingly out of date, publication of a revised edition of the *Dictionary of Organic Compounds*, containing literature references as late as 1941–42, is particularly welcome. Revision of volume I has been extensive. Inclusion of many new compounds, most notably in recently investigated fields of natural products, has resulted in the enlargement of the volume by 366 pages. Generous increase in the number of cross-references, and inclusion of references to 'Organic Syntheses' and to abstracts, in the case of recent patent literature, enhance the value of the volume.

It is a little difficult to appreciate the principle governing the revision of literature references. Frequently many new derivatives are included without any new references being appended; compounds, now included for the first time, sometimes carry only very early references. Relatively little revision of physical data, such as the dissociation constants of acids and bases, seems to have been effected, although many additions to such data have recently appeared. The plan of collecting all references together at the end of an article, without indicating to which specific derivative or property they refer (especially, for example, when *dl-*, *d-*, and *l-* forms exist), somewhat detracts from their value.

These, however, are relatively minor criticisms, and the editors and their collaborators are to be congratulated on the compilation of such a useful and well-selected collection of information in a relatively small compass.

J.W.B.

### THE CHEMISTRY AND USES OF STARCH

Starch and its Derivatives, *by J. A. Radley. Pp. xii + 558. Chapman & Hall Limited, London. Second edition, revised,* 1943. 36*s. net.*

Although this book is one of a series of monographs on applied chemistry, the description of industrial uses of starch constitutes not more than half of it, the rest of the text being devoted to an attempt to cope with the gigantic mass of literature on what may be called the pure chemistry of starch. The author doubtless hoped thereby to strike a more even balance between pure and applied than was attained in the first edition, in which the technical aspect predominated.

The applied sections in the new edition have been revised, and extended by the incorporation of additional material. They now provide a source of information, much of which is not otherwise readily accessible, of the greatest value not only to technical chemists concerned with the manufacture or the utilization of starch, but also to chemists who are not specialists in these fields but who are anxious to keep abreast of industrial progress.

The sections of the book which deal with the structure and properties of starch represent a laudable attempt to bring some sort of order out of the chaos of contradictory data which has accumulated in the course of a century. This is a herculean task and cannot be done in the space available. These sections become, for the most part, merely compilations of names and views—particularly views—which often are mutually irreconcilable. Compilations of this kind have, of course, their usefulness, and chemists will be grateful to Mr Radley for the diligence which has collected together so many references. Nevertheless, one feels that a monograph is not intended to be an uncritical account of as many hypotheses as may be crowded into an allotted number of pages. One would have preferred to see the author take a stand on the thesis of his own interpretations and not simply to record what *A* thought in 1840 cheek by jowl with *B*'s opinion in 1940 and leave it at that. In one chapter, for instance, the author contrives in fifteen pages of script to refer to more than 200 original papers. Such compression clearly precludes any critical assessment of the relative merit of the work or the workers mentioned.

### GUIDE TO THE FUNGI

A Dictionary of the Fungi, *by G. C. Ainsworth and G. R. Bisby. Pp. vii + 359, with 10 Plates. The Imperial Mycological Institute, Kew, Surrey.* 1943. 20*s. net.*

This book provides a list of all the generic names of fungi (with synonyms) in use up to the end of 1939, with interesting information about many of the genera and a glossary of terms used in mycology and plant pathology. It will undoubtedly be very useful to all students of the fungi, a group of organisms of bewildering variety. Included in the dictionary are references to penicillin, ergot, edible and poisonous fungi, fairy-rings, etc., that even the man in the street has heard of. More information might well have been given about some of the genera, and in this respect the book compares not too favourably with Willis's *Dictionary of the Flowering Plants and Ferns*, on which it has been partly modelled. Above all, a dictionary should be complete, and it is the more regrettable that names given to fungi since 1939 are not included in that they can be found elsewhere.

This dictionary is written chiefly in Basic English. However great the merits of Basic for certain purposes, one can see no possible advantage in its use here sufficient to compensate for circumlocution and a certain lack of precision. In a scientific treatise it is strange to read 'kept from taking place' instead of 'prevented.' F. T. BROOKS

### THE PLANTS OF SANTO DOMINGO

Catalogus Florae Domingensis (Catálogo de la Flora Domínicana). Parte I: Spermatophyta, *by R. M. Moscosco. Pp. xlviii + 732. New York, published for the University of Santo Domingo.* 1943. *N.p.*

Santo Domingo or Española (Hispaniola) is the most central and second largest of the Greater Antilles. The island is mountainous, four mountain groups being recognized, and the highest summits exceed 3,000 m. The rocks and soils are very diversified and the climate is hot and humid. Such physical conditions are favourable to the development of a rich flora and vegetation.

The Director of the Instituto Botánico (R. M. Moscosco), whose *Introducción* is dated September 1938 from Santiago, R.D., and January 1942 from New York, has published what would appear to be a very complete list of all the species of seed-bearing plants known to occur in the island, both in Haiti and the República Dominicana. The list is correctly described in the title as a Catalogus (Catálogo) and not as a Flora, for it contains only names, localities of species ranges within the island, habitat notes, and occasionally brief references to native names and habitats. There are no keys, descriptions, or figures of the plants recorded, which include cultivated as well as native species. The sequence of families is that of Engler's system. The format is excellent and there are adequate indices to Latin and vernacular names. The work should prove of value to all students of New World tropical floras.

W. B. TURRILL

### INORGANIC MALNUTRITION IN PLANTS

The Diagnosis of Mineral Deficiencies in Plants by Visual Symptoms: A Colour Atlas and Guide, *by T. Wallace. Pp. vi + 116, with numerous coloured illustrations. H.M. Stationery Office, London.* 1943. 10*s. net.*

War-time cropping and the vital need for obtaining as much food as possible from the land have emphasized the importance of recognizing signs of faulty nutrition at an early stage in the growth of crops. Dr Wallace gives an excellent summary of essential points in the nutrition of plants and discusses the capacity of soils to supply the mineral nutrients, including trace elements, which are necessary for their healthy development. After a review of methods of determining mineral deficiencies in crops, he gives details of the visual method of diagnosis in the field, including the use of selected indicator plants. The special feature of the book, however, is the valuable series of colour photographs, which will assist greatly in recognizing the symptoms in both agricultural and horticultural crops. Following diagnosis by the rapid visual method, it is often possible to save a failing crop, for instance by timely spraying.

The book will serve as a most valuable guide, particularly for technical officers and advisers. W.G.O.

### MEDICAL APPLICATIONS OF SPECTROPHOTOMETRY

Spectrophotometry in Medicine, *by Ludwig Heilmeyer; translated by A. Jordan and T. L. Tippell. Pp. xiv + 280. Adam Hilger Limited, London.* 1943. 30*s. net.*

The publishers of this book have a reputation second to none in the world as manufacturers of optical instruments for spectroscopy and polarimetry. It is, perhaps, less well known that they are also responsible for publishing certain excellent monographs dealing with the principles of using such optical instruments and also with their application in various branches of science. It is to be regretted that this book will do nothing to increase their reputation as publishers. It is a translation of a monograph published in Germany in 1932—before, it is true, German science began rapidly to slide down the slippery totalitarian path. The use of spectrophotometric methods for diagnostic purposes in medicine may conceivably have made no progress in Germany during the last eleven years. They have been extensively developed during that period elsewhere, particularly in the United States. It is difficult, therefore, to conceive the object of publishing a translation of this book that was not at the same time a thorough revision, bringing all methods into line with current practice based upon the most recent advances. Detailed technical criticism would require more space than is available on the present occasion; all that can with propriety be said is that the book, at the published price of 30s., is poor value indeed, particularly when compared with the excellent monograph by Dr Morton, reviewed in the April 1943 number of ENDEAVOUR. Not only was Dr Morton's book a lucid exposition of a subject in which he himself is a practical expert, it was also a complete revision of the first edition, which appeared as recently as 1935. This revision was found necessary after seven years because of advances that are in no way confined to the application of spectroscopy in the vitamin and hormone field. Similar advances have been made in the spectroscopic study of haemoglobin and its derivatives and breakdown products and of other blood and urinary pigments; the translation of Heilmeyer's book takes no account of these, and the six-page supplement on recent apparatus, with special reference to that manufactured by Messrs Adam Hilger Limited, is quite inadequate to make this book of theoretical interest or practical value.

A. L. BACHARACH

### 'J. J.'

The Life of Sir J. J. Thomson, O.M., *by Lord Rayleigh. Pp. x + 299, with 9 illustrations. Cambridge University Press, London.* 1942. 18*s. net.*

In an appendix to this book, between three and four pages are occupied by a list of the distinctions conferred upon Thomson. But thousands of Cambridge men, and others, remember him with affection as the unassuming and friendly 'J.J.,' never too busy as Cavendish Professor of Physics to give a word of help or advice, or as Master of Trinity to take a personal interest in every College activity. The main features of his classical contributions to atomic physics are universally known. Lord Rayleigh, who—as a distinguished physicist himself and an intimate friend of Thomson—was doubly qualified for the task, has written a biography in which Thomson's scientific work is described as simply as possible and shown in its relation with the work of his pupils. The human side of the story is by no means neglected, and Lord Rayleigh's narrative leaves us with a clear and illuminating picture of one of the most notable figures of recent times. Though, in the words of Sir William Bragg, Thomson, 'more than any man, was responsible for the fundamental change in outlook which distinguishes the physics of this century from that of the last,' he never lost his unaffected modesty and genuinely desired to be regarded as an ordinary plain man.

# Notes on contributors

E. CHAIN, *D.Phil.*,
Was born in 1906 in Berlin, but is of Russian descent. The son of an industrial chemist, he graduated in Germany in chemistry and physiology. Political events caused him to come to England in 1933, and he has since acquired British nationality. He worked for two years at Cambridge in Sir F. Gowland Hopkins' laboratory, and is now University Demonstrator in Chemical Pathology at Oxford, in the Sir William Dunn School of Pathology. He has always been interested in the biological aspects of chemistry, on which he has published many original papers. His chief relaxation is music.

H. W. FLOREY,
*M.A., M.B., B.S., Ph.D., F.R.S.*,
Was born in 1898, and was educated at the Universities of Adelaide and Oxford. He was Rhodes scholar for South Australia in 1921, John Lucas Walker student at Cambridge in 1924, and Rockefeller Travelling Fellow in America in 1925. He became a Fellow of Gonville and Caius College, Cambridge, in 1926, and in the following year was appointed Huddersfield Lecturer in Special Pathology in the University of Cambridge. From 1931 to 1935 he was Hunter Professor of Pathology in the University of Sheffield, and in the latter year was elected to his present post as Professor of Pathology in the University of Oxford. His contributions to technical journals on pathological and physiological subjects have been both numerous and distinguished. He was made a Fellow of the Royal Society in 1941. His favourite recreation is lawn tennis.

F. J. NORTH, *D.Sc., F.G.S.*,
Is Keeper of the Department of Geology in the National Museum of Wales and the present President of the South Wales Institute of Engineers. His principal activities are in the popularizing of geology, by means of museum exhibitions designed to illustrate the relation between geology and everyday life, and through studies in the history of the subject. He is a keen and energetic advocate of the inclusion of geology in the curriculum of schools. He took part in the early development of broadcast talks on scientific themes and is interested in the aid which geology can render to archaeology. Besides his many original papers on scientific subjects, he has also written on cartography, place-names, and British and foreign museum methods and technique.

G. D. HALE CARPENTER,
*M.B.E., D.M., M.R.C.S., L.R.C.P.*,
Is the son and grandson of scientists, for his father, P. H. Carpenter, F.R.S., and grandfather, W. B. Carpenter, F.R.S., were both well-known marine biologists. He was born at Eton College in 1882, and was educated at Bradfield, St Catherine's College, Oxford, and St George's Hospital, London. Primarily interested in the living creature and its environment, he studied medicine and joined the Colonial Medical Service. In 1910 he was seconded to investigate the biology of the tsetse-fly, the carrier of sleeping sickness, which had been ravaging Uganda, and was appointed to the sleeping sickness commission of the Royal Society. For several years he lived on uninhabited islands in Lake Victoria, corresponding meanwhile with the late E. B. Poulton, under whose inspiring influence he wrote many articles on polymorphic mimetic butterflies and other examples of mimicry. During the war of 1914–18 he served throughout the East African campaign, and when peace was restored was appointed specialist officer to advise the Uganda Government on the control of sleeping sickness. He retired from the Colonial Service in 1930, and in 1933 was elected to the Hope Professorship of Zoology (Entomology) in the University of Oxford. He has been Vice-president of the Linnaean Society and President of the South-eastern Union of Scientific Societies. His recreations are gardening, boating, and (but only in Cornwall!) walking.

J. C. SWALLOW,
*Ph.D., A.M.I.Chem.E.*,
Was born at Kingsbridge, Devon, in 1903, and was educated at the Universities of London and Leiden (Holland). At Leiden, he carried out research on low temperature problems, working in the cryogenic laboratories with the late Kamerlingh Onnes. He joined the research staff of Brunner, Mond and Company in 1924, and in 1941 became research manager of the Alkali Group of Imperial Chemical Industries. A year later he was appointed director of research of the Plastics Group of Imperial Chemical Industries. He is fond of travel.

LEON L. OSSOWSKI,
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Was born in 1905, and was educated in Poland and Germany. After graduating in forestry at Poznań University, he entered the Polish State Forest Service in 1927. Specializing in entomology and phytopathology he was appointed officer in charge of forest protection in the state forests in Poland. In this capacity he was responsible for the measures taken to combat the outbreak of pine noctuid in the province of Pomorze in 1931–33, using contact poison on a large scale. In 1935 he was appointed Chief Forester of State Forests in Poland, and also became Lecturer in Forestry (Forest Protection and Zoology). He is the author of two books and numerous papers and articles on his special subjects. He fought in the Polish Army in 1939, was taken prisoner, escaped to France (where he fought again), and finally reached Great Britain after Dunkirk. For a time, his services were employed by the Ministry of Supply, but he has recently been appointed head of the Forestry Department of the Polish Ministry of Reconstruction. He is a prizeman of the Royal Scottish Forestry Society.

E. T. WHITTAKER,
*M.A., Hon. LL.D. (St. Andrews and California Universities), Hon. Sc.D. (Dublin), Hon. D.Sc. (National University of Ireland), F.R.S.*,
Is Professor of Mathematics in the University of Edinburgh, and has the unique distinction of being a member of all the three national academies in the British Isles, viz. the Royal Society of London (Vice-president, 1934–35), the Royal Society of Edinburgh (President since 1939), and the Royal Irish Academy (Vice-president, 1911–12). He is a Foreign Member of the *Reale Accademia dei Lincei*, a Corresponding Member of the Royal Society of Naples, and one of the two members in Great Britain of the *Pontificia Accademia Scientiarum*. A prominent member of the Catholic laity, he is Honorary President of the Newman Association (the union of Catholic university graduates). In 1931 he was awarded the Sylvester Medal of the Royal Society.

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